Elm Architecture
Functional Programming

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Outline

Elm language

Elm Language

- Selections
- Iterations
- Sequences

Union types

HTTP in Elm

Architecture

- The Monad
- The Model
- The View
- And Updates

REST assignment

Values

- Strings
  - `"Hello"`
  - `"Hello"++" "++"World!"` is `"Hello World!"`
- Numbers
  - `7`
  - `22.67`
  - `2 + 3 * 4` is `14`
  - `9/2` is `4.5`
  - `9//2` is `4`

Functions

```
> isNegative n = n < 0
<function>

> isNegative 4
False

> isNegative -7
True

> isNegative (-3 * -4)
False
```

Selections

```
> if True then "hello" else "world"
"hello"

> if False then "hello" else "world"
"world"
```

Lists

```
> names = [ "Alice", "Bob", "Chuck" ]
["Alice","Bob","Chuck"]

> List.isEmpty names
False

> List.length names
3

> List.reverse names
["Chuck","Bob","Alice"]
```

Lists

```
> numbers = [1,4,3,2]
[1,4,3,2]

> List.sort numbers
[1,2,3,4]

> double n = n * 2
<function>

> List.map double numbers
[2,8,6,4]
```

Tuples

```
> import String

> goodName name = \
|   if String.length name <= 20 then \
|     (True, "name␣accepted!") \
|   else \
|     (False, "name␣was␣too␣long")

> goodName "Tom"
(True, "name␣accepted!")
```

Records

```
> point = { x = 3, y = 4 }
{ x = 3, y = 4 }

> point.x
3

> bill = { name = "Gates", age = 57 }
{ age = 57, name = "Gates" }

> bill.name
"Gates"
```

Records

```
> .name bill
"Gates"

> List.map .name [bill,bill,bill]
["Gates","Gates","Gates"]

> { bill | name = "Nye" }
{ age = 57, name = "Nye" }

> { bill | age = 22 }
{ age = 22, name = "Gates" }
```

Records

```
> under70 {age} = age < 70
<function>

> under70 bill
True

> under70 { species = "Triceratops", age = 68000000 }
False
```

Primitives and Lists

```
> "hello"
"hello" : String

> not True
False : Bool

> round 3.1415
3 : Int
```

```
> [ "Alice", "Bob" ]
[ "Alice", "Bob" ] : List String

> [ 1.0, 8.6, 42.1 ]
[ 1.0, 8.6, 42.1 ] : List Float

> []
[] : List a
```

Functions

```
> import String
> String.length
<function> : String -> Int

> String.length "Supercalifragilisticexpialidocious"
34 : Int

> String.length [1,2,3]
-- error!

> String.length True
-- error!
```

Lambdas - anonymous functions

```
> \n -> n / 2
<function> : Float -> Float

> (\n -> n / 2) 128
64 : Float

> oneHundredAndTwentyEight = 128.0
128 : Float

> half = \n -> n / 2
<function> : Float -> Float

> half oneHundredAndTwentyEight
64 : Float

> half n = n / 2
<function> : Float -> Float
```

Functions with more arguments

```
> divide x y = x / y
<function> : Float -> Float -> Float

> divide 3 2
1.5 : Float

> divide x = \y -> x / y
<function> : Float -> Float -> Float

> divide = \x -> (\y -> x / y)
<function> : Float -> Float -> Float
```

Functions - again

```
divide 3 2
```

Functions - again

```
divide 3 2
```

```
(divide 3) 2                   -- 1: Implicit parentheses
```

Functions - again

```
divide 3 2
```

```
(divide 3) 2                -- 1: Implicit parentheses
```

```
((\x -> (\y -> x / y)) 3) 2 -- 2: Expand ’divide’
```

Functions - again

```
divide 3 2
```

```
(divide 3) 2                -- 1: Implicit parentheses
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((\x -> (\y -> x / y)) 3) 2 -- 2: Expand 'divide'
```

```
(\y -> 3 / y) 2             -- 3: Replace x with 3
```

Functions - again

```
divide 3 2
```

```
(divide 3) 2                            -- 1: Implicit parentheses
```

```
((\x -> (\y -> x / y)) 3) 2 -- 2: Expand ’divide’
```

```
(\y -> 3 / y) 2                         -- 3: Replace x with 3
```

```
3 / 2                                   -- 4: Replace y with 2
```

Functions - again

```
divide 3 2
```

```
(divide 3) 2                -- 1: Implicit parentheses
```

```
((\x -> (\y -> x / y)) 3) 2 -- 2: Expand ’divide’
```

```
(\y -> 3 / y) 2             -- 3: Replace x with 3
```

```
3 / 2                       -- 4: Replace y with 2
```

```
1.5                         -- 5: Do the math
```

Type annotations

```elm
half : Float -> Float
half n =
  n / 2

divide : Float -> Float -> Float
divide x y =
  x / y

askVegeta : Int -> String
askVegeta powerLevel =
  if powerLevel > 9000 then
    "It's␣over␣9000!!!"
  else
    "It␣is␣" ++ toString powerLevel ++ "."
```

If statements

```
 > if True then "hello" else "world"
```

```
if 10 == 10 then "hi"
```

If statements

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`if 10 == 10 then "hi"` **Won't compile!**

If statements

```
> if True then "hello" else "world"
```

if 10 == 10 then "hi" **Won't compile!** if 10 == 10 then "hi" else "ho"

If statements

```
> if True then "hello" else "world"
```

`if 10 == 10 then "hi"` **Won’t compile!** `if 10 == 10 then "hi" else "ho"`

Remember that **everything must have a return type**!

case matches

```
case n of
  0 -> "Zero"
  1 -> "One"
  _ -> "Moar"
```

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case n of
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Error!: this ‘case‘ does not have branches for all possibilities.

case matches

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case n of
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```

```
case n of
  0 -> "Zero"
  1 -> "One"
  2 -> "Two"
```

Error!: `this ‘case‘ does not have branches for all possibilities.` Because everything has a fixed type, we *know* whether we will match everything!

This is seriously **cool**!

Debugging

How do you normally debug in Java?

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What is the problem with that in Elm?

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Everything needs a return type. Also debugging/println/logging.

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How do you normally debug in Java?
What is the problem with that in Elm?
Everything needs a return type. Also debugging/println/logging.
Solution is to encapsulate the side-effect:

```
    import Debug

    if (Debug.log "A is" a) == 10 then "hi" else "ho" -- "A
```

Classic language building blocks

In LISP we still had the classic programming constructs. But Elm is pure functional, so what then?

Sequence
?

Selection (control-logic)
?

Iteration
?

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Sequence	
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	Easy: Expressions instead of statements
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	Medium: Recursion!

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In LISP we still had the classic programming constructs. But Elm is pure functional, so what then?

Sequence

Hard: Monads

Selection (control-logic)

Easy: Expressions instead of statements

Iteration

Medium: Recursion!

Destructuring - Pattern matching

- In functions calls
- In `case`-`of` constructs
- In `let`-`in` constructs

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- □ In let-in constructs

```
p = (3.5, 4.2)
l = [7, 9, 13],
n = { name = "Kurt", age = 34 }:
```

Destructuring - Pattern matching

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```

```
manhattan point =
  let
    (x, y) = point
  in
    x + y
```

```
manhattan p -- 7.7
```

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  let
    (x, y) = point
  in
    x + y
```

```
manhattan p -- 7.7
```

```
describe {name, age} =
  name ++ "␣is␣" ++ (toString age)
```

```
describe n -- "Kurt is 34"
```

Destructuring - Pattern matching

- In functions calls
- In case-of constructs
- In let-in constructs

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p = (3.5, 4.2)
l = [7, 9, 13],
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```

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manhattan point =
  let
    (x, y) = point
  in
    x + y
```

```
manhattan p -- 7.7
```

```
describe {name, age} =
  name ++ "␣is␣" ++ (toString age)
```

```
describe n -- "Kurt is 34"
```

```
sum list =
  case list of
    []           -> 0
    head :: tail -> head + (sum tail)
```

```
sum l -- 29
```

Selection

You can use `if-then-else` and `case-of` constructs in Elm:

```
fact n =
  if n == 0 then 1
  else n*(fact (n - 1))

case x of
  Just a  -> a
  Nothing -> 0
```

Exercise 1 - Selections in Elm

Create an Elm function that

Calculates the third product $5 * 6 = 30$ of a list of points, if the list is empty the result should be 0, if the list has less than three elements the result should be 1:

```
points = [(1, 2), (3, 4), (5, 6), (7, 8)]
```

Exercise 1 solution

```elm
import Html exposing (text)

main =
  text (toString (exercise1 points))

points = [(1,2), (3,4), (5,6), (7,8)]
-- points = [(1,2), (3,4)]
-- points = []

exercise1 list =
  case list of
    [] -> 0
    _ :: _ :: (z1, z2) :: _ -> z1*z2
    _ -> 1
```

Iteration

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There aren't any, you have to use recursion!

Iteration

Where did the `while` and `for` loops go?

There aren't any, you have to use recursion! But you get help from the List core module:

- Create lists with:

```
List.repeat 3 (0,0) == [(0,0),(0,0),(0,0)]
List.range 3 6 == [3, 4, 5, 6]
1 :: [2,3] == [1,2,3]
1 :: [] == [1]
List.append [1,1,2] [3,5,8] == [1,1,2,3,5,8]
['a','b'] ++ ['c'] == ['a','b','c']
```

- Map and fold lists:

```
List.map sqrt [1,4,9] == [1,2,3]
List.map2 (+) [1,2,3] [1,2,3,4] == [2,4,6]
List.sum [1,2,3,4] == 10
List.product [1,2,3,4] == 24
```

Exercise 2 - List based factorial

Create a function `factorial` that calculates $n!$ for $n > 0$ using the `List` module, especially `range` and `product` are interesting.

Exercise 3 - Iterations in Elm

Create a function, that calculates:

$$4 \cdot \sum_{n=1}^{100} (-1)^{n+1} \cdot \frac{1}{2n-1}$$

Exercise 3 - Iterations in Elm

Create a function, that calculates:

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Hint, that is the same as:

$$4 \cdot \left(\frac{1}{1} - \frac{1}{3} + \frac{1}{5} - \frac{1}{7} + \frac{1}{9} - \frac{1}{11} + \cdots + \frac{1}{197} - \frac{1}{199} \right)$$

Sequence

In Elm, monads are hidden in the architecture, but we will return to monads in **Haskell**.

But surprisingly, we don't need much sequential processing creating web pages!

Maybe

Maybe

In Java

```java
Person getPerson(Long id) throws IOException {
  return database.getPersonById(id);
}
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```
type Maybe a
  = Just a
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  = Just a
  | Nothing
```

```elm
getPerson : Int -> Maybe Person
getPerson id = ...
```

Union types 1/2

A union type is a piece of memory which can take the form of one or more values, but only one at the time.

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```
maybeBaby : Maybe String
```

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```

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type Maybe a
  = Just a
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```

```
maybeBaby : Maybe String
```

`maybeBaby` can now either be `Just String` or `Nothing`

It **cannot be anything else**.

Capturing errors

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}
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Person getPerson(Long id) throws IOException {
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Did we forget something? Yes! The exception!

```
type Either a b
  = Left a          -- The exception
  | Right b         -- The success
```

Capturing errors

In Java

```java
Person getPerson(Long id) throws IOException {
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}
```

Did we forget something? Yes! The exception!

```elm
type Either a b
  = Left a        -- The exception
  | Right b       -- The success
```

```elm
getPerson : Int -> Either Exception Person
getPerson id = ...
```

Union types 2/2

A union type is a piece of memory which can take the form of one or more values, but only one at the time.

```
type Either a b
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HTTP

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  = Ok value
  | Err error
```

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For a HTTP call, what would you expect as output?

```
type Result error value
  = Ok value
  | Err error
```

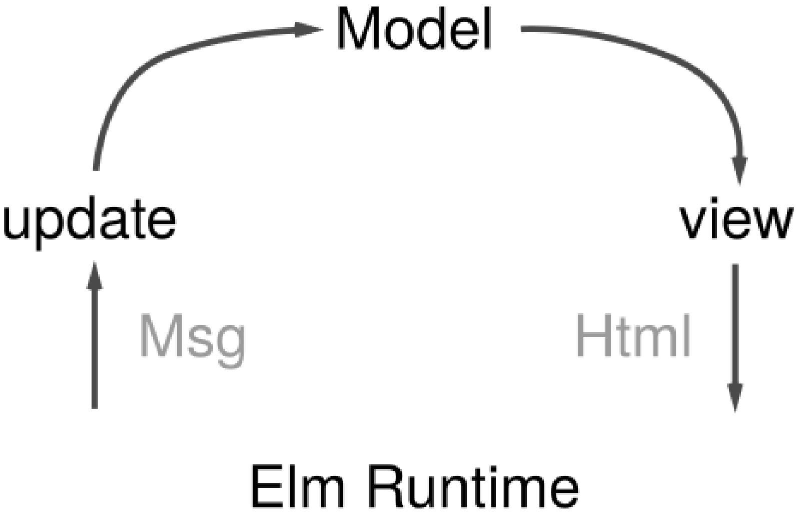
Union type

HTTP request

```
type alias Request a
  = Request a
```

```
getString : String -> Request String
```

HTML updates



HTTP to HTML

To insert the HTTP result, we have to put it into the HTML page with a `Cmd`

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```
type Msg
  = NewContent ?
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HTTP to HTML

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```
type Msg
  = NewContent ?
```

```
type Msg
  = NewContent (Result Http.Error String)
```

Getting the HTTP Result

Now we have a `HTTP Request` and a way to insert it into our view

But how do we get the `HTTP Result`?

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```
HTTP.send : (Result Error a -> msg) ->
            Request a -> Cmd msg
```

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```
HTTP.send : (Result Error a -> msg) ->
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Translated:

- `HTTP.send` takes two parameters

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Now we have a `HTTP Request` and a way to insert it into our view

But how do we get the `HTTP Result`?

```
HTTP.send : (Result Error a -> msg) ->
            Request a -> Cmd msg
```

Translated:

- `HTTP.send` takes two parameters
- 1: One function which takes a result and converts it into something else

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HTTP.send : (Result Error a -> msg) ->
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Translated:

- HTTP.send takes two parameters
- 1: One function which takes a result and converts it into something else
- 2: One request which performs the HTTP call

Getting the HTTP Result

Now we have a `HTTP Request` and a way to insert it into our view

But how do we get the `HTTP Result`?

```
HTTP.send : (Result Error a -> msg) ->
            Request a -> Cmd msg
```

Translated:

- `HTTP.send` takes two parameters
- 1: One function which takes a result and converts it into something else
- 2: One request which performs the HTTP call
- `HTTP.send` returns the message extracted from the first function

Putting it together

```
import Http

type Msg = Click | NewBook (Result Http.Error String)

update : Msg -> Model -> Model
update msg model =
  case msg of
    Click -> ( model, getWarAndPeace )

    NewBook (Ok book) -> ...

    NewBook (Err _) -> ...

getWarAndPeace : Cmd Msg
getWarAndPeace =
  Http.send NewBook <|
    Http.getString "https://example.com/some_book.md"
```

Putting it together

Live coding!

Architecture

The Monad - the program

```
import Html exposing (..)
import Html.Attributes exposing (..)
import Html.Events exposing (onInput)

main =
  Html.beginnerProgram
    { model = model
    , view = view
    , update = update
    }
```

Architecture

Model

```elm
type alias Model =
  { name : String
  , password : String
  , passwordAgain : String
  }

model : Model
model =
  Model "" "" ""
```

Architecture

View

```
view : Model -> Html Msg
view model =
  div []
    [ input
      [ type_ "text"
      , placeholder "Name"
      , onInput Name ] []
    , input
      [ type_ "password"
      , placeholder "Password"
      , onInput Password ] []
    , input
      [ type_ "password"
      , placeholder "Re-enter␣Password"
      , onInput PasswordAgain ] []
    , viewValidation model
    ]
```

Architecture

View

```
viewValidation : Model -> Html msg
viewValidation model =
  let
    (color, message) =
      if model.password == model.passwordAgain then
        ("green", "OK")
      else
        ("red", "Passwords␣do␣not␣match!")
  in
    div [ style [("color", color)] ] [ text message ]
```

Architecture

Update

```elm
type Msg
    = Name String
    | Password String
    | PasswordAgain String

update : Msg -> Model -> Model
update msg model =
  case msg of
    Name name ->
      { model | name = name }
    Password password ->
      { model | password = password }
    PasswordAgain password ->
      { model | passwordAgain = password }
```

Exercise 5 - Hello anybody

Create a hello world web site with one input field and a text field that shows `"Hello "` and the content of the input field when a button is pushed.

```
$ mkdir hello
$ cd hello
```

Copy the following into `Main.elm`

```
import Html exposing (text)

main =
  text "Hello,␣World!"
```

And:

```
$ elm-package install -y
$ elm-reactor
```

The code from today can be found here: `https://github.com/cphbus-functional-programming/elm-exercises`

REST assignment

Write a server in a language of your choice with two HTTP REST methods:

1. `GET /counter`: increments and returns an integer counter
2. `PUT /counter/{value}`: sets the counter to `value`

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Write an Elm client using the model - view - update architecture. Your client must have:

1. A model containing one counter `Model { counter:  Int }`
2. A view with two HTML buttons (get and set) as well as the counter in an HTML `H2` element
3. An update part which can 1) get the counter value from your REST service and 2) set the counter to a fixed value of 1

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Hand in `before` **17th March 12:00**
Review `before` **18th March 23:59**