Practical Functional Programming

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About me

My name is **Jiahao!**

- CS Undergraduate @ NUS
- Coreteam @ NUS Hackers
- Elixir Enthusiast
  - Written several articles about Elixir
  - Did summer intern at Betafi using Elixir full-time in production
  - Done Advent of Code 2020/21/22/23 in Elixir

Agenda Today

1. What is this talk about?
2. Prerequisites
3. What is functional programming?
4. Why functional programming?
5. Brief history of Elixir
6. Why Elixir?
7. **!Elixir fundamentals**
8. **!Introducing Phoenix**
9. Conclusion

What this talk is about

- ✅ Fundamental understanding of FP
- ✅ New perspective on FP
- ✅ Introduce basic web dev with Elixir + Phoenix

- ❌ Convince you that FP >> all else
- ❌ Go super in-depth with Elixir syntax
- ❌ Teach everything about Phoenix
- ❌ Claim Elixir is the only production ready FP language

Prerequisites

- Have Elixir installed
- Have SQLite3 installed (optional)
- Fundamentals of programming (variables, loops, functions, etc)

Accompanying Guide

More information-dense compared to these slides

[https://hckr.cc/practical-elixir]

What is functional programming? (FP)

```
lst
    .stream()
    .map(x -> x * 2)
    .reduce(1, (acc, el) -> acc * el)
    .collect(Collectors.toList());
```

From CS2030S?

```
quicksort2 :: (Ord a) => Array Int a -> Array Int a
quicksort2 inputArr = runSTArray $ do
stArr <- thaw inputArr
let (minIndex, maxIndex) = bounds inputArr
quicksort2Helper minIndex (maxIndex + 1) stArr
return stArr
quicksort2Helper :: (Ord a)
=> Int
-> Int
-> STArray s Int a
-> ST s ()
quicksort2Helper start end stArr = when (start + 1 < end) $ do
pivotIndex <- partition stArr start end
quicksort2Helper start pivotIndex stArr
quicksort2Helper (pivotIndex + 1) end stArr
```

Haskell?

A (somewhat) formal definition...

> *Programming paradigm* that involves *composing programs from functions* and treating these functions as *first-class citizens* in the language

So, what is FP?

> “Functional programming is an *alternative way of thinking* and solving problems by using *functions as the fundamental building blocks*”

Traits of FP

1. First-class functions
2. Pure functions
3. Recursion
4. Referential transparency
5. Type system

First-class functions

Pass functions as arguments and return functions

Pure functions

$$f : x \mapsto y$$

The only change in program state happens with the input and output of the function

No other changes to be made to program state (i.e. *side effects*)

Recursion

$$f(x) = f(x-1) + f(x-2)$$

No iterative loops

Function calling itself till some base case is achieved

Referential transparency

```
x = [1, 2, 3]

def fn(y) do
    y = [4, 5, 6]
end

fn(x)
x       # still [1, 2, 3]
```

Once initialized, the value of a variable cannot change

Type system

Defines set of rules that govern what a type can contain

Useful for creating domain-specific types

Why FP?

1. Improves problem solving skills
2. Pure functions reduce worry of side effects
3. Referential transparency avoids unintended state changes
4. Robust type system == representing domain logic better

Why FP, actually?

Because it's fun!!

Introducing Elixir

Brief history of Elixir

- Created by Jose Valim in 2011
- Former Ruby on Rails core contributor
- Incorporates FP referential transparency with Erlang VM + OTP
- Syntax similar to Ruby's syntax
- Designed to build highly concurrent and distributed systems

Why Elixir?

- Gentle introduction to functional programming concepts
- Used by major companies like Discord, Heroku, Mozilla, and Betafi
- Used in various fields like IoT (Nerves), distributed systems (OTP), and web development (Phoenix)

Agenda till this point

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6. Why Elixir? **<- You are here!**
7. **!Elixir fundamentals**
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Elixir fundamentals

1. Types
2. Pattern matching
3. Modules
4. Functions
5. Conditionals
6. Recursion
7. Enumerables
8. Mix (covered in guide)

Running Elixir code

Terminal

```
iex
```

```
λ ~/ iex
Erlang/OTP 26 [erts-14.2.1] [source] [64-bit] [smp:8:8] [ds:8:8:10] [async-threads:1] [jit] [dtrace]

Interactive Elixir (1.16.0) - press Ctrl+C to exit (type h() ENTER for help)
iex(1)>
```

Elixir scripts

1. Create file ending with `*.exs`
2. Run file via `elixir <file>.exs`

Types

- Dynamically typed
- Relies on dialyzer to provide type checking using type annotations
- Referential transparency is important

Types roadmap

Very fast to cover! All fundamental data types in other languages

1. Basic types
2. Arithmetic
3. Boolean operations
4. nil
5. Atoms
6. Strings
7. Structural comparison
8. Lists
9. Tuples
10. Keyword lists
11. Maps

Basic types

```elixir
x = 1          # integer
x = 0.5        # float
x = true       # boolean
x = :atom      # atom
x = "elixir"   # string
```

Arithmetic

```
iex(1)> 1 + 1
2
iex(2)> 2 * 3
6
iex(3)> 3 / 2
1.5
iex(4)> 3 - 2
1
iex(5)> div(3, 2)
1
iex(6)> rem(3, 2)
1
```

Boolean operations

```
iex(17)> true and true
true
iex(18)> true and false
false
iex(19)> false or true
true
iex(20)> not true
false
```

Short circuit operators!

`nil`

Absence of value

`nil` and `false` are falsy values with everything else as truthy values

Atoms

```
iex(24)> x = :apple
:apple
iex(25)> x == :apple
true
```

Strings

```
iex(26)> str = "Hello world!"
"Hello world!"

iex(27)> str <> " said the computer"
"Hello world! said the computer"

iex(31)> "The computer said '#{str}'"
"The computer said 'Hello world!'"
```

Structural comparisons

```
iex(32)> 1 == 1
true
iex(33)> "a" == "a"
true
iex(34)> 1 != 2
true
iex(35)> 1 < 2
true
iex(36)> 1 == 1.0
true
```

Strict comparisons using `===` and `!===`

Lists

Linked lists

```
iex(2)> x = ["hi", 1, true, :atom]
["hi", 1, true, :atom]

iex(3)> [1, 2] ++ [4, 5]
[1, 2, 4, 5]

iex(4)> [1, 2, 3] -- [2, 3]
[1]

iex(5)> length(x)
4
```

Tuples

Fixed-sized & contiguous memory

```
iex(7)> t = {:ok, "hello", 1}
{:ok, "hello", 1}

iex(8)> elem(t, 2)
1
iex(9)> elem(t, 1)
"hello"

iex(10)> tuple_size(t)
3
```

Zero-based index

Keyword lists (1)

Pass options to functions

```
iex(11)> String.split("hello world  another ", " ", trim: true)
["hello", "world", "another"]
```

Declaration

```
iex(12)> x = [a: 0, a: 1, b: 2]
[a: 0, a: 1, b: 2]
iex(15)> [{:a, 0}, {:a, 1}, {:b, 2}]
[a: 0, a: 1, b: 2]
```

Keyword lists (2)

Accessing elements

```
iex(16)> x[:b]
2
```

Properties:

1. Atoms as keys
2. Order dependent
3. Allows duplicate keys

Maps (1)

Hashmaps in other languages

Store key-value pairs

```
iex(18)> m = %{:a => 1, "hello" => "world", 2 => :c}
%{2 => :c, :a => 1, "hello" => "world"}

iex(19)> m[:a]
1
iex(20)> m[2]
:c
iex(21)> m.a
1
```

Maps (2)

Updating values

```
%{map | key: new_value}
```

Properties:

1. Anything as keys
2. Not order dependent
3. Disallows duplicate keys (values are just overridden)

Pattern matching

`=` operator -> "match" operator

Matches the LHS and RHS of an expression

```
iex(1)> x = 1 # This is assigning the value 1 to variable x
1
iex(2)> 1 = x # This is matching the value of variable x to 1 (checks if LHS == RHS)
1
iex(3)> 2 = x # This fails because variable x holds value of 1, so the match fails
** (MatchError) no match of right hand side value: 1
    (stdlib 5.2) erl_eval.erl:498: :erl_eval.expr/6
    iex:3: (file)
```

Pattern matching (Lists)

```
iex(8)> l = [1, 2, 3, 4, 5, 6]
[1, 2, 3, 4, 5, 6]
iex(9)> [h | t] = l
[1, 2, 3, 4, 5, 6]
iex(10)> h
1
iex(11)> t
[2, 3, 4, 5, 6]
```

Pattern matching (Tuples)

```
iex(3)> x = {:a, "hello", 1}
{:a, "hello", 1}
iex(4)> {atom_var, str_var, num_var} = x
{:a, "hello", 1}
iex(5)> atom_var
:a
iex(6)> str_var
"hello"
iex(7)> num_var
1
```

Pattern matching (Ignore operator)

```
iex(12)> [a | _] = l
[1, 2, 3, 4, 5, 6]
iex(13)> a
1
```

Pattern matching (Maps)

```
iex(15)> %{:a => a, "hello" => world_var, 2 => _} = d
%{2 => :b, :a => 1, "hello" => "world"}
iex(16)> a
1
iex(17)> world_var
"world"
```

Pattern matching (Deeply nested structures)

```
iex(18)> n = [:a, %{"hello" => "world", :b => %{"nested" => "value"}}]
[:a, %{:b => %{"nested" => "value"}, "hello" => "world"}]

iex(19)> [_, %{:b => %{"nested" => nested_var}}] = n
[:a, %{:b => %{"nested" => "value"}, "hello" => "world"}]

iex(20)> nested_var
"value"
```

Modules

Way to package like functions

```
defmodule Math do
    def add(a, b) do
        a + b
    end

    def subtract(a, b) do
        a - b
    end
end

IO.puts(Math.add(5, 3))
```

Functions

```
def function_name(function_parameters) do
    # ...
end
```

Impure functions are allowed but discouraged

Return values

Automatically set as the final expression in function body

```
def format_person(name, age, school) do
    "#{name} is #{age} years old and attends #{school}"
end
```

Quality of life

Omit parentheses and use of `end`

```
def foo, do: 5
```

Function overloading

Same name, differing parameters

```
def foo(a, b), do: a + b
def foo(a), do: a
def foo, do: nil
```

Default arguments

Must be last in parameter list

```
def minus(a, b \\ 0) do
    a - b
end
```

Pattern matching

$$f(n) = \begin{cases} 0, n = 0 \\ 1, n = 1 \\ f(n-1) + f(n-2) \end{cases}$$

```
def fib(0), do: 1
def fib(1), do: 1
def fib(n), do: fib(n - 1) + fib(n - 2)

def fib(_), do: nil # Drop down clause
```

Guard clauses

Validate argument before function body is run

```
def fib(n) when n < 0, do: nil
def fib(n) when n == 0 or n == 1, do: 1
def fib(n), do: fib(n - 1) + fib(n - 2)

def abs_minus(a, b) when a < b, do: b - a
def abs_minus(a, b), do: a - b
```

Limited to certain functions

Anonymous functions

Declared without `def`

Used to pass functions around or as return values

```
pow_two = fn x -> x * x end
pow_two.(4) # returns 16
```

Closures

Anonymous functions have access to variables that are in scope when declared

```
def foo do
    x = 42
    bar = fn -> x * 2 end
    bar.() # returns 84
end
```

Conditionals

1. `case`
2. `if`
3. `cond`
4. `unless`

case

Compare given value against many patterns

```
case {1, 2, 3} do
    {1, 2, 5} -> "This will not return"
    {4, 5, 6} -> "Neither will this"
    {1, x, 3} -> "This will work with any #{x}"
    _ -> "This is used as the 'default' case"
end
```

Works with guard clauses too

Pin operator (`^`)

"Locks" variable at time of use to prevent re-assignment

```
x = 5
case {1, 2, 3} do
    {1, 2 ^x} -> "This will also try matching {1, 2, 5} and fail"
    _ -> "This will be the result"
end
```

`if`

Same as other languages

No `elif` clause

```
if x > 3 do
    "Greater"
else
    if x < 0 do
        "Negative"
    else
        "Lesser"
    end
end
```

`case`

Effectively a nested `if` statement

```
cond do
    x > 3 -> "Greater"
    x < 0 -> "Negative"
    true -> "Lesser"
end
```

`unless`

Expression must evaluate to `false` to run

```
unless true do
    "This will not return"
end
```

Returning conditionals

1. Expressions can be returned
2. Conditionals are expressions

∴ Conditionals can be returned

```
def foo do
    if true do
        "This is returned"
    else
        "This isn't"
    end
end
```

Recursion

Function calling itself

Tail-call optimization: using only one stack frame for recursive calls

(Only if last expression is recursive call)

Recursive patterns (Mapping)

```python
x = [1, 2, 3]
for i in range(len(x)):
    x[i] *= 2
print(x)
```

Python

```elixir
def map([], res), do: res
def map([xi | rest], res),
    do: map(rest, res ++ [xi * 2])
```

Elixir

Recursive patterns (Reducing)

```python
x = [1, 2, 3, 4]
s = 0
for i in range(len(x)):
    s += x[i]
print(s)
```

Python

```elixir
def sum([], acc), do: acc
def sum([xi | rest], acc),
    do: sum(rest, acc + xi)
```

Elixir

Recursive patterns (Filtering)

```python
x = [1, 2, 3, 4, 5]
filtered = []
for i in range(len(x)):
    if x[i] & 1 == 1:
        filtered.append(x[i])
```

Python

```elixir
def filter([], acc), do: acc

def filter([xi | rest], acc)
    when Integer.is_even(xi),
    do: filter(rest, acc)

def filter([xi | rest], acc),
    do: filter(rest, acc ++ [xi])
```

Elixir

Enumerables

`Enum` module containing frequently used utility functions

1. `Enum.all?`
2. `Enum.any?`
3. `Enum.at`
4. `Enum.filter`
5. `Enum.map`
6. `Enum.reduce`

Function chaining

Used when passing output of one function to input of another using pipe (`|>` operator)

```
Enum.map(Enum.filter(1..10, fn x -> Integer.is_odd(x) end), fn x -> x * 2 end)
```

Do this instead

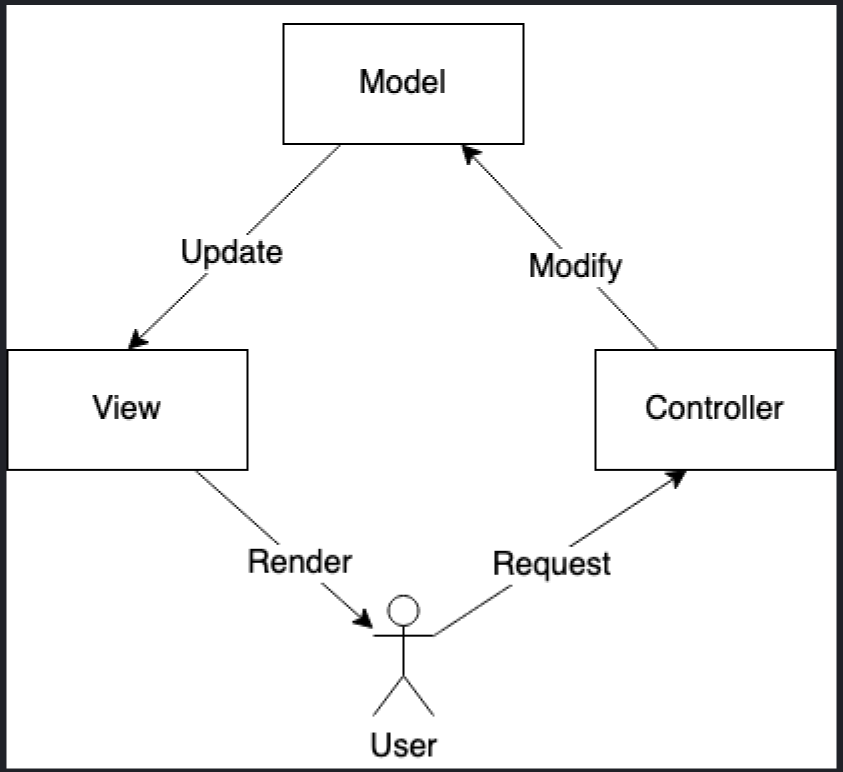
```
1..10
|> Enum.filter(fn x -> Integer.is_odd(x) end)
|> Enum.map(fn x -> x * 2 end)
```

Time for Phoenix!

What is Phoenix?

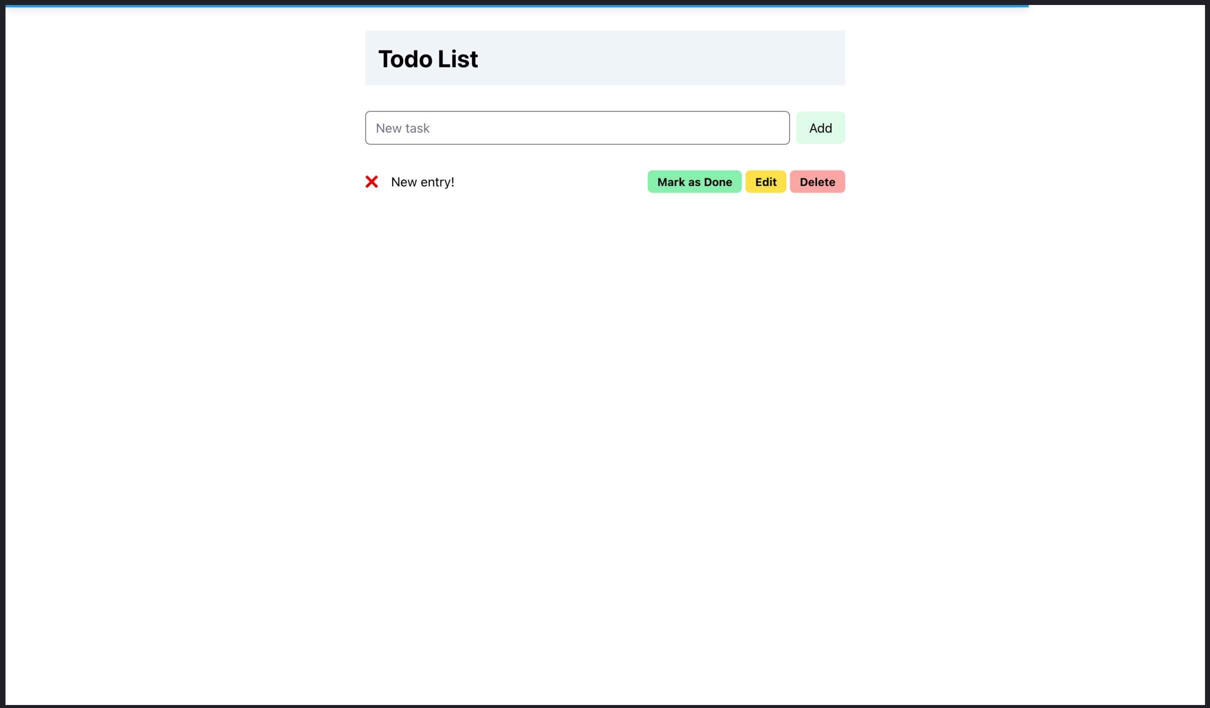
- Server-side web framework
- Created by Chris McCord
- Modeled after Ruby on Rails framework

Model-View-Controller (MVC) pattern



What will we do?

Building a simple to-do list application



Structure

1. Directory structure of Phoenix projects
2. Request lifecycle
3. Representing to-do items in Elixir
4. Anatomy of routers
5. Creating a new HTTP endpoint
6. Rendering to-do list
7. Adding dynamic actions to to-do list
8. Persisting data with Ecto & SQLite3 (may not cover)

Getting started

Install Phoenix CLI

```
mix archive.install hex phx_new
```

Setup new Phoenix project

```
mix phx.new practical_elixir_demo --database sqlite3
```

Navigate to folder

```
cd practical_elixir_demo
```

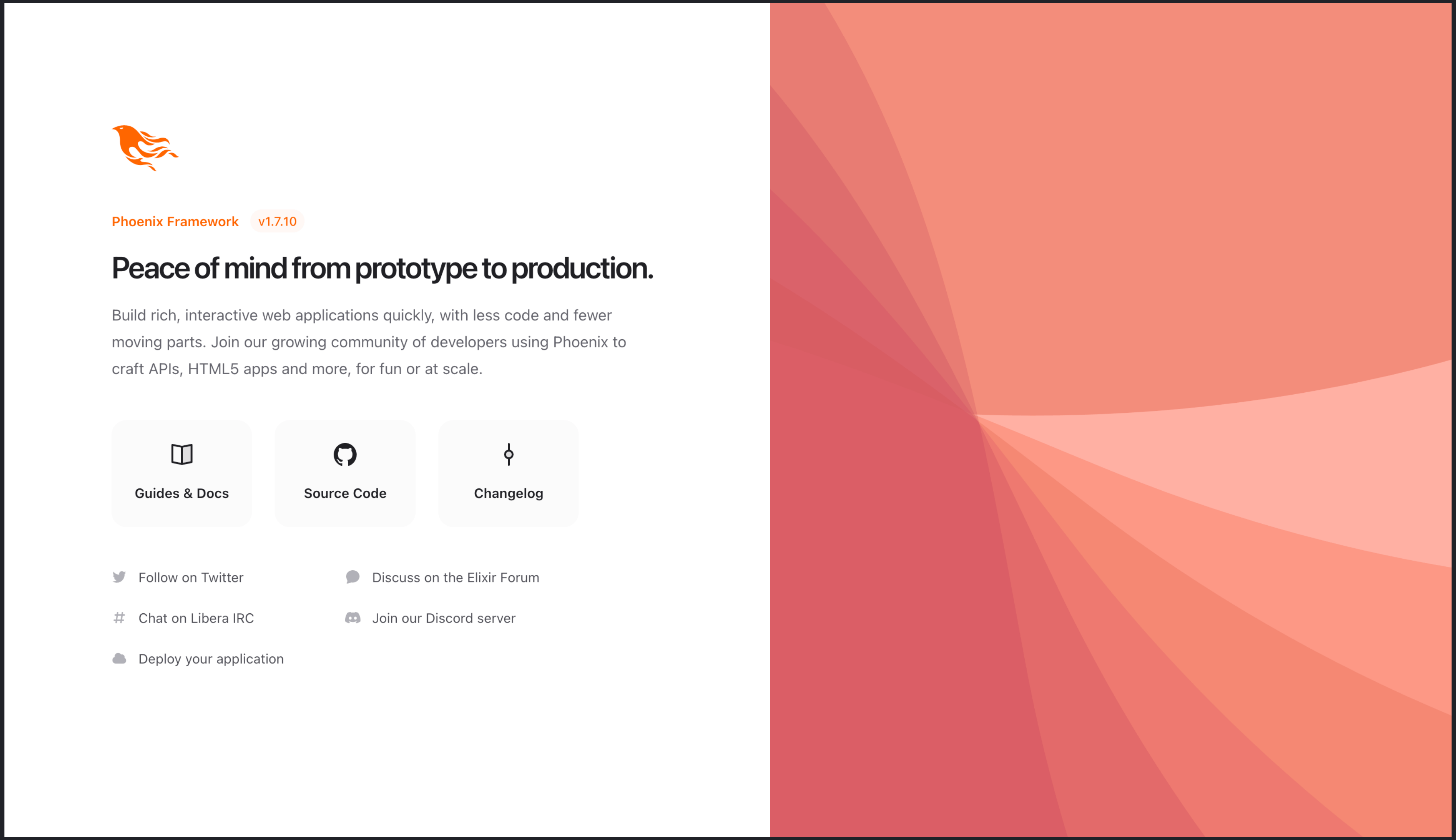
Getting started

Setup database

```
mix ecto.create
```

Run application

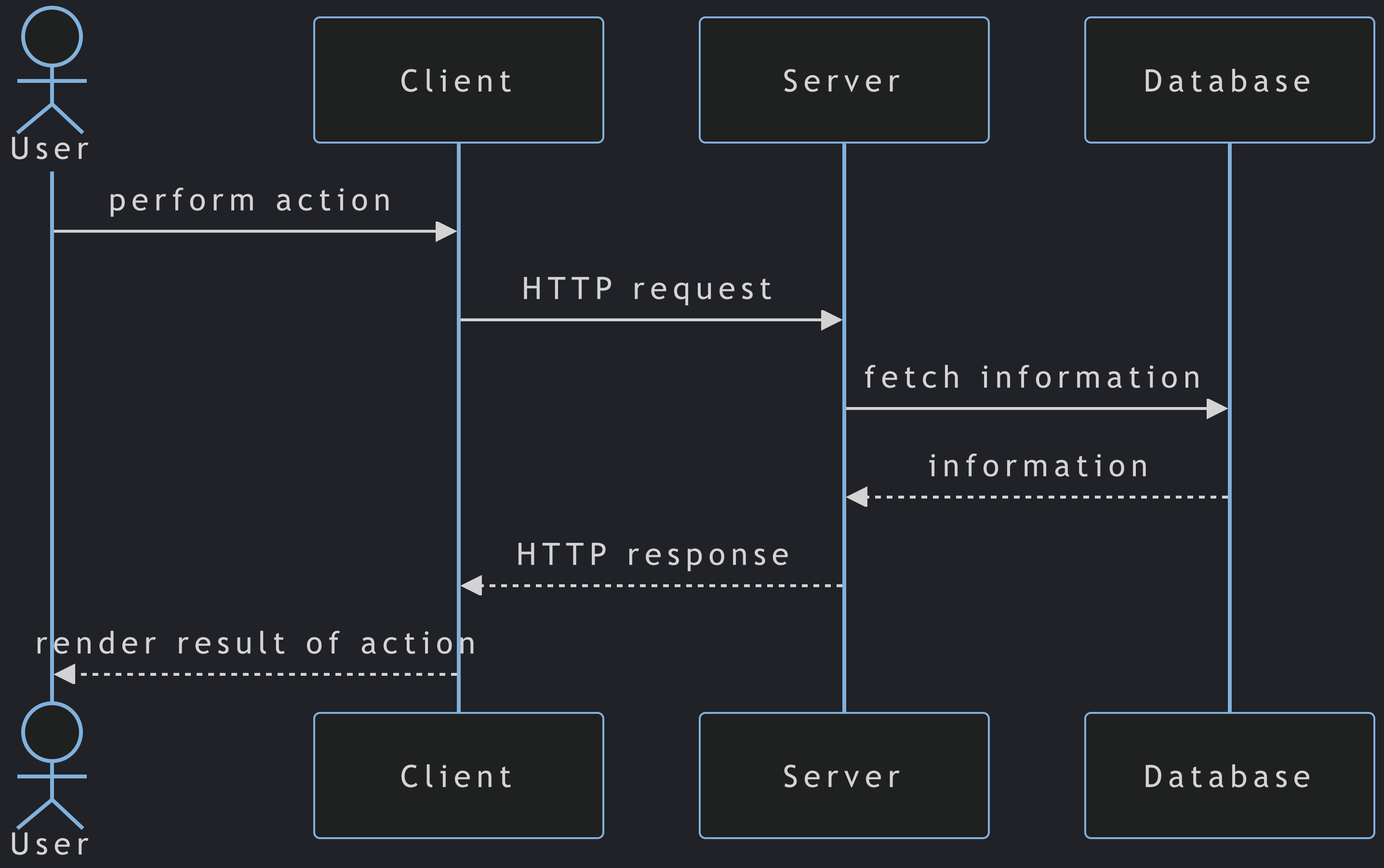
```
mix phx.server
```


Phoenix Framework
v1.7.10
Peace of mind from prototype to production.
Build rich, interactive web applications quickly, with less code and fewer moving parts. Join our growing community of developers using Phoenix to craft APIs, HTML5 apps and more, for fun or at scale.
Guides & Docs
Source Code
Changelog
Follow on Twitter
Discuss on the Elixir Forum
Chat on Libera IRC
Join our Discord server
Deploy your application

Directory structure

```
.
├── .formatter.exs
├── .gitignore
├── README.md
├── _build
├── assets
│   ├── css
│   ├── js
├── config
├── lib
│   ├── practical_elixir_demo/
│   ├── practical_elixir_demo_web/
├── mix.exs
├── mix.lock
├── practical_elixir_demo_dev.db
├── priv
└── test
```

Request lifecycle



Basic HTTP

GET

POST

PUT

DELETE

/endpoint

Structs in Elixir

```elixir
defmodule PracticalElixirDemo.Todo.TodoItem do
  @derive Jason.Encoder
  defstruct [:title, description: nil, is_done?: false]
end
```

Anatomy of a router

1. `use`
2. Pipelines
3. Scopes
4. Declaring routes

Creating new endpoint

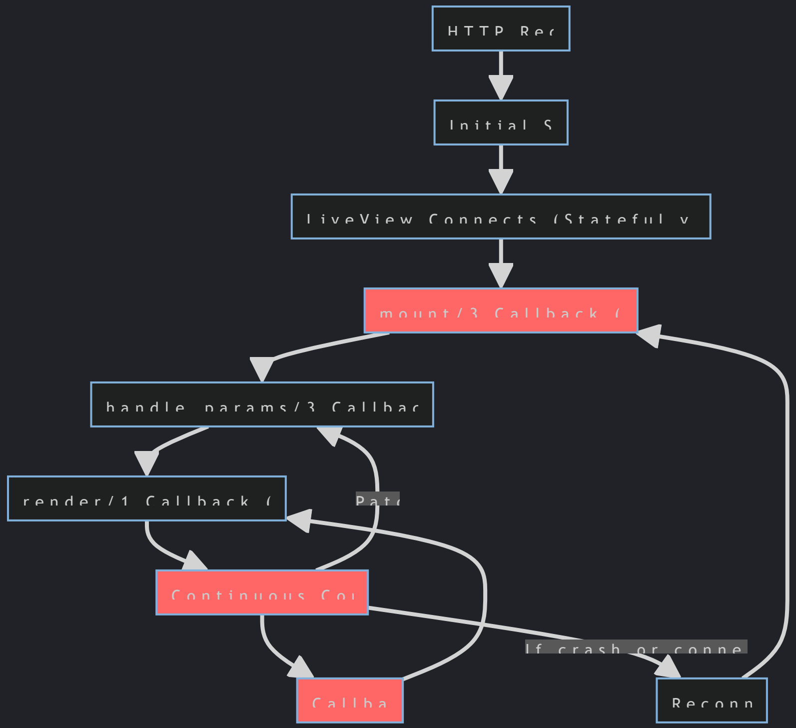
1. Add route to scope in `router.ex`
2. Add controller action in respective controller file

Creating new page

1. Add route to scope in `router.ex`
2. Add controller action to render view
3. Add template file to render page with content

"But I don't want to use JavaScript!"
- Presumably you

LiveView lifecycle



Migrating to LiveView

For this workshop:

```
git fetch
git switch liveview-base
```

Full steps in guide

Thank you!

Feedback