Elixir/OTP

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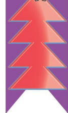
The Pragmatic Programmers



Metaprogramming Elixir

Write Less Code, Get More Done (and Have Fun!)

Chris McCord
(author of the Phoenix framework)

Edited by Jacquelyn Carter

Copyrighted Material

Elixir IN ACTION

Saša Jurić

Copyrighted Material

Inspiration and some code taken from these books. (They're great!)

Overview

1. Firehose-style introduction to Elixir
2. Actors (or “processes”)
3. Erlang/OTP - Elixir/OTP
   a. Supervisor
   b. GenServer
   c. Application
4. Elixir Macros
5. Slackbot

Elixir?

- Ruby syntax, compiled to Core Erlang to run on BEAM
- Functional (side-effects, no mutability)
- Modern toolset to develop Erlang programs
- All the Erlang stuff
    - Fault Tolerance
    - Scalability
    - Distribution
    - Responsiveness
    - Live code reloading

Tools

- The REPL
  iex
- The build-tool
  mix
- The package repository
  hex *(https://hex.pm/)*
- Editors
  Emacs/IntelliJ/Atom/Sublime/Visual Studio Code/Vim

Presentation source

https://github.com/m1dnight/hello_world

https://github.com/m1dnight/slackbot

http://bit.ly/xaopotp

Basic Elixir Syntax

- Variables

```
> x = 5
```

- Lambdas

```
> f = fn(x,y,z) -> x + y + z end
> f.(1,2,3)
```

- Function calls

```
> IO.puts("Hello, World")
> IO.puts "Hello,World"
```

- Modules

```
defmodule MyModule do
  def my_function() do
    5
  end
end
```

- Data types
  - Atoms: `:this_is_an_atom`
  - Strings: `"This is a string"`
    `~s("quoted string")`
  - Lists: `[1,2,:foo]`
  - Bools: `true false :true :false`
  - Null: `nil :nil`
  - Tuples: `{:foo, "bar", 1}`
  - Maps: `m = %{"key" => :value}`
    `m.foo` or `m["foo"]`
  - Bitstrings: `<<1, 2, 3>>`
    `<<257::16>>` 16 bits for that value
    `== <<1, 1>>`

Pattern Matching

- Basics

```
> x = 1  # Check if 1 matches with pattern x
> 1 = 1  # Check if 1 matches with 1
> _ = 4  # Underscore wildcard
```

- Datastructures

```
> %{:key => val} = %{:key => 5, :kay => 6} # Bind val to 5
> [x,y,z | xs] = [1,2,3,4]
> x = 5
> {^x, y} = {5, 6} # Unifies y with 6
> {^x, y} = {6,7}  # Error
```

http://elixir-lang.org/getting-started/pattern-matching.html

Pattern Matching - Function Clauses

```
def divide(_x, 0), do: {:error, "division by zero"}

def divide(x,1), do: {:ok, x}

def divide(x,y) where is_integer(x) and is_integer(y) do:
  {:ok, x / y}
end

def divide(x,y) do:
  {:error, "can only divide integers"}
end
```

Hello, World v1

```
defmodule Greeting do
  @message “Hello “
  def greet(greetee) do
    IO.puts @message <> greetee
  end

  def insult(_insultee) do
    exit(:i_refuse)
  end
end
```

Basic Actor Operations

- Creating an actor with spawn/1

```
> actor_id = spawn(fn() -> IO.puts “I’m another actor” end)
```

- Creating an actor with spawn/3

```
> actor_id = spawn(IO, :puts, [“I’m another actor”])
```

- Sending a message to another actor with send/2

```
> send(actor_id, {:this, “is”, “a”, “message”})
```

  - Asynchronous
  - Delivery is in order, guaranteed delivery to inbox (or you will find out otherwise if you use links)
- Receiving a message with send

```
receive do
  pattern -> exp
end
```

http://elixir-lang.org/getting-started/processes.html
http://erlang.org/faq/academic.html

Inbox priorities

```
> send(self(), {:first, 1})
> send(self(), {:second, 2})
```

```
receive do
  {:second, _val} -> :first
after 0 ->
  receive do
    {:first, _val} -> :second
  end
end
```

http://elixir-lang.org/getting-started/processes.html

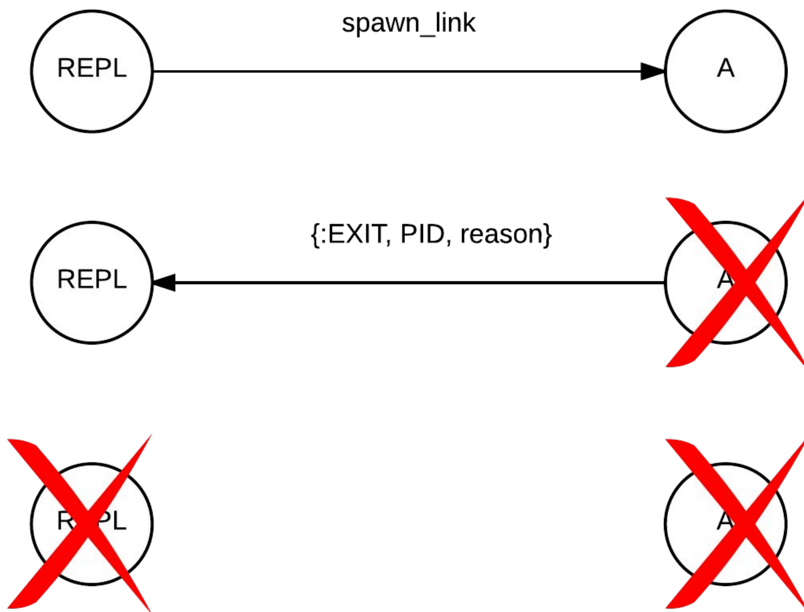
Hello, World v2

```
defmodule Greetingv2 do
  def loop() do
    receive do
      {:greet, greetee} ->
        IO.puts "Hello " <> greetee
        loop()
      {:insult, _insultee} ->
        exit(:i_refuse)
    end
  end
end
```

```
iex(1)> pid = spawn(Greetingv2, :loop, [])
#PID<0.108.0>
iex(2)> send(pid, {:greet, "XAOP"})
Hello XAOP
{:greet, "XAOP"}
iex(3)> send(pid, {:insult, "XAOP"})
{:insult, "XAOP"}
iex(4)> send(pid, {:greet, "XAOP"})
{:greet, "XAOP"}
iex(5)>
```

Links and Monitors

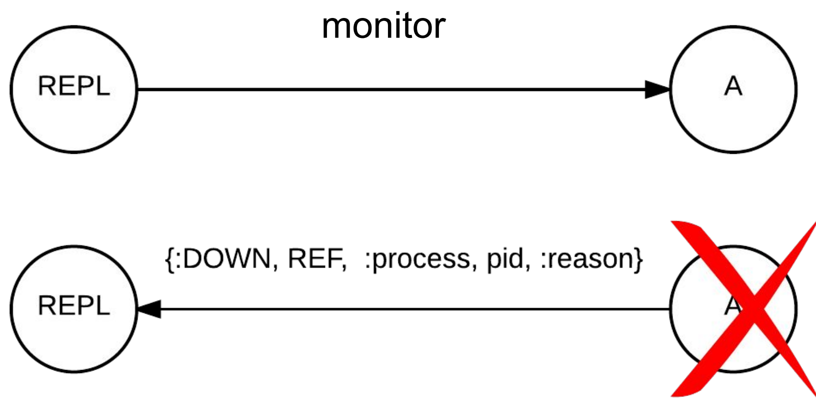
When a process dies, it emits a **special** message to all linked processes



http://elixir-lang.org/getting-started/processes.html

Links and Monitors

When a process dies, it emits a special message to all linked processes




```
> monitor(spawn(..))
```

http://elixir-lang.org/getting-started/processes.html

Hello, World v2

```elixir
defmodule Greetingv2 do
  def loop() do
    receive do
      {:greet, greetee} ->
        IO.puts "Hello " <> greetee
        loop()
      {:insult, _insultee} ->
        exit(:i_refuse)
    end
  end
end
```

```
iex(1)> pid = spawn_link(Greetingv2, :loop, [])
#PID<0.108.0>
iex(2)> send(pid, {:greet, "XAOP"})
Hello XAOP
{:greet, "XAOP"}
iex(9)> send(pid, {:insult, "XAOP"})
** (EXIT from #PID<0.106.0>) :i_refuse

Interactive Elixir (1.4.2) - press Ctrl+C to exit
(type h() ENTER for help)
iex(1)>
```

Hello, World v2

```elixir
defmodule Greetingv2 do
  def loop() do
    receive do
      {:greet, greetee} ->
        IO.puts "Hello " <> greetee
        loop()
      {:insult, _insultee} ->
        exit(:i_refuse)
    end
  end
end
```

```
iex(6)> pid = spawn_link(Greetingv2, :loop, [])
#PID<0.126.0>
iex(7)> Process.flag(:trap_exit, true)
false
iex(8)> send(pid, {:insult, "Elixir"})
{:insult, "Elixir"}
iex(9)> flush()
{:EXIT, #PID<0.126.0>, :i_refuse}
:ok
```

Elixir/OTP

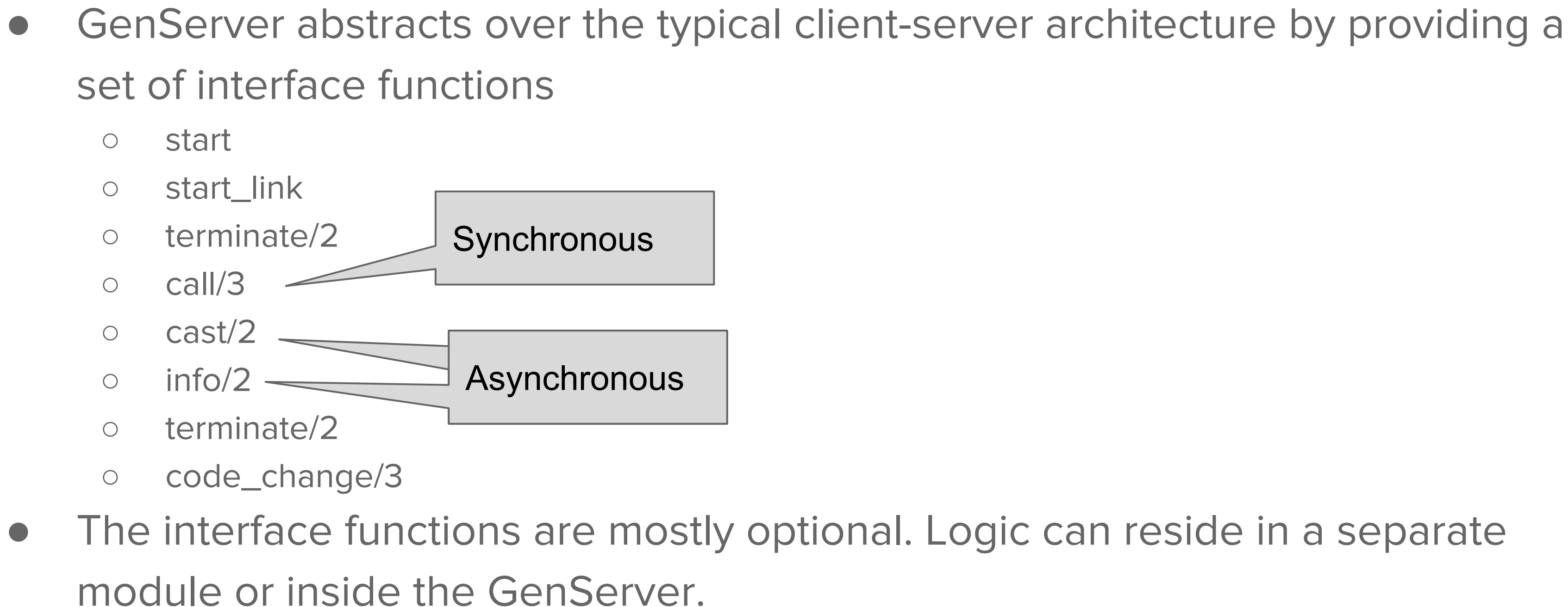
Erlang/OTP?

- Erlang Open Telecom Platform
  - I.e., years worth of engineering from Ericsson!

- Abstractions over common behaviours
  - Supervisors: Make sure processes keep running
  - GenServer: Generic server interface
  - Custom behaviour interfaces
  - Application
  - ..

- Shapes your train of thought and implementation to obtain reusable parts

GenServer



https://hexdocs.pm/elixir/GenServer.html

Hello, World - Server

```
defmodule Greeting.Server do
  use GenServer
  def start_link(args \\ []) do
    GenServer.start_link(__MODULE__, args, name: __MODULE__)
  end
  def init([]) do
    {:ok,[]}
  end
  def handle_call({:greet, greetee}, _from, state) do
    IO.puts "Hello, " <> greetee
    {:reply, :ok, state}
  end
  def handle_call({:insult, insultee}, _from, state) do
    exit(:i_refuse)
  end
end
```

On starter process, short as possible

On server process, short as possible, blocking

Hello, World - Server

```
iex(2)> {:ok, pid} = GenServer.start_link(Greeting.Server, [])
{:ok, #PID<0.128.0>}
iex(3)> GenServer.call(pid, {:greet, "XAOP"})
Hello, XAOP
:ok
iex(4)> GenServer.call(pid, {:insult, "XAOP"})
** (EXIT from #PID<0.124.0>) :i_refuse
22:21:31.990 [error] GenServer #PID<0.128.0> terminating
** (stop) :i_refuse
    ...
Last message: {:insult, "XAOP"}
State: []
```

Supervisor

- Supervisors supervise other processes. Used to build trees of processes and manages them by (re)starting them.
  - init/1

- Supervision trees allow you to contain failures in a tree.

- Strategies
  - one_for_one
  - one_for_all
  - rest_for_one
  - simple_one_for_one

Hello, World - Supervisor

```elixir
defmodule Greeting.Supervisor do
  use Supervisor

  def start_link(args \\ []) do
    Supervisor.start_link(__MODULE__, [args])
  end

  def init(args) do
    children =
      [
        worker(Greeting.Server, [])
      ]

    supervise(children, strategy: :one_for_one)
  end
end
```

https://hexdocs.pm/elixir/Supervisor.html#content

Hello, World - Supervisor

```
iex(1)> self()
#PID<0.106.0>
iex(2)> Supervisor.start_link(Greeting.Supervisor, [])
{:ok, #PID<0.109.0>}
iex(3)> GenServer.call(Greeting.Server, {:greet, "XAOP"})
Hello, XAOP
:ok
iex(4)> GenServer.call(Greeting.Server, {:insult, "XAOP"})
** (exit) exited in: GenServer.call(Greeting.Server, {:insult, "XAOP"}, 5000)
iex(4)> GenServer.call(Greeting.Server, {:greet, "XAOP"})
Hello, XAOP
:ok
iex(5)> self()
#PID<0.106.0>
```

GenEvent

- One generic event management process
- Many event handlers
- Many event producers
- Callbacks
    - code_change/3
    - handle_call/2
    - handle_event/2
    - handle_info/2
    - init/1
    - terminate/2

GenEvent

```elixir
# Define an Event Handler
defmodule LoggerHandler do
  use GenEvent

  # Callbacks

  def handle_event({:log, x}, messages) do
    {:ok, [x | messages]}
  end

  def handle_call(:messages, messages) do
    {:ok, Enum.reverse(messages), []}
  end
end
```

```elixir
> {:ok, mgr} = GenEvent.start_link([])
> GenEvent.add_handler(pid, LoggerHandler, [])
> GenEvent.notify(pid, {:log, 1})
> GenEvent.call(pid, LoggerHandler, :messages)
```

Application

"A reusable component with specific functionality that can be started and stopped as a whole while being reusable in other projects."

- Second coarsest grained component in Elixir/OTP
- Created using mix: `mix new greeting`
- Dependencies (Applications)
- Configuration files
- Wrapper around Supervisor

Hello, World - Application

```
$ mix new hello_world
* creating README.md
* creating .gitignore
* creating mix.exs
* creating config
* creating config/config.exs
* creating lib
* creating lib/hello_world.ex
* creating test
* creating test/test_helper.exs
* creating test/hello_world_test.exs

Your Mix project was created successfully.
```

Hello, World - Application

```elixir
defmodule HelloWorld do
  use Application

  def start(_type, _args) do
    Supervisor.start_link(Greeting.Supervisor, [])
  end
end
```

- Returns `{:ok, pid}` where pid is the PID of the Supervision tree
- `_type`: Mode of operation. Does not matter unless distributed (failover/takeover)
- `_args`: Passed in via mix.exs (application state/parameters)
- Optional implementation of `stop/1` for cleanup

Hello, World - Application Config

```elixir
defmodule HelloWorld.Mixfile do
  use Mix.Project

  def project do
    [app: :hello_world,
     version: "0.1.0",
     elixir: "~> 1.4",
     build_embedded: Mix.env == :prod,
     start_permanent: Mix.env == :prod,
     deps: deps()]
  end

  ...
```

```elixir
  ...
  def application do
    [extra_applications: [:logger],
     mod: {HelloWorld, []}
    ]
  end

  defp deps do
    []
  end
end
```

Hello, World - Application

```
$ iex -S mix
Interactive Elixir (1.4.2) - press Ctrl+C to exit (type h() ENTER for help)
iex(1)> GenServer.call(Greeting.Server, {:greet, "XAOP"})
Hello, XAOP
:ok
```

Hello, World - Failover

- Run same application on distributed system
- Only one server is actually active, rest is idle
- Other server takes over upon failure
- Predefined order of take-over
- If higher-priority server is back up, takes back control

Hello, World - Failover

```
def start_link(args \\ []) do
    GenServer.start_link(__MODULE__, args, name: {:global, __MODULE__})
end
```

Hello, World - Failover

```
def start_link(args \\ []) do
    GenServer.start_link(__MODULE__, args, name: {:global, __MODULE__})
end
```

Hello, World - Failover Config

```
[{kernel,
  [{distributed, [{hello_world,
                   0,
                  [a@anorak, {b@anorak, c@anorak}]}]},
   {sync_nodes_mandatory, []},
   {sync_nodes_optional, [b@anorak, c@anorak]},
   {sync_nodes_timeout, 5000}
  ]
 }
].
```

http://erlang.org/doc/design_principles/distributed_applications.html

Hello, World - Failover Startup

- Server

```
export name="a"
iex --sname "$name"
    -pa _build/dev/lib/hello_world/ebin
    --app hello_world
    --cookie cookie
    --erl "-config config/$name"
```

- Client

```
iex --cookie cookie --sname client -S mix run --no-start
```

DEMO TIME

Macros

- Quoting returns the AST representation

```
> ast = quote do: 1 + 2
```

- ASTs are represented in Elixir terms

```
> {:+, [context: Elixir, import: Kernel], [1,2]}
```

- Unquoting injects a term into a macro

```
> quote do: unquote(5 * 2) + 1
{:+, [context: Elixir, import: Kernel], [10, 1]}
```

- ASTs can be evaluated using Code.eval_ast/1

```
> Code.eval_quoted(ast)
  {2, []}
```

- Macros can be expanded using the Macro module

```
> Macro.expand_once(unless true, do: false, __ENV__)
```

Macro Hygiene

A macro can never capture variables in it’s expansion environment.

But if you really want to..

```
defmacro dirty(exp) do
   quote do
     var!(x) = unquote(exp)
   end
 end
```

```
> x = 10
10
> MyMacro.dirty(100)
100
> x
100
```

The unless macro

```
> unless boring() == false do
      sleep()
      true
  end
> nil
```

The unless macro

```
defmodule MyMacros do
  defmacro unless(expression, do: body) do
   quote bind_quoted: [body: body, expression: expression] do
      if !expression do
        body
      end
    end
  end
end
```

The unless macro

```
> require MyMacro
> unless true, do: 5
  nil
> unless false, do: 1 + 2
  3
```

Simple Unit Tests

```
defmodule MathTest do
  use Assertion
  test "integers can be added and subtracted" do
    assert 1 + 1 == 2
    assert 2 + 3 == 5
    assert 5 - 5 == 10
  end
  test "integers can be multiplied and divided" do
    assert 5 * 5 == 25
    assert 10 / 2 == 5
  end
end
```

Simple Unit Tests

```
defmodule Assertion do
  defmacro __using__(_options) do quote do
    import unquote(__MODULE__)
    Module.register_attribute __MODULE__, :tests, accumulate: true @before_compile
unquote(__MODULE__)

  defmacro test(description, do: test_block) do
    test_func = String.to_atom(description)
    quote do
      @tests {unquote(test_func), unquote(description)}
      def unquote(test_func)(), do: unquote(test_block)
    end
  end
  # ...
end
```

The most reliable, stable, resilient, distributed, performant, concurrent, awesome Slack bot

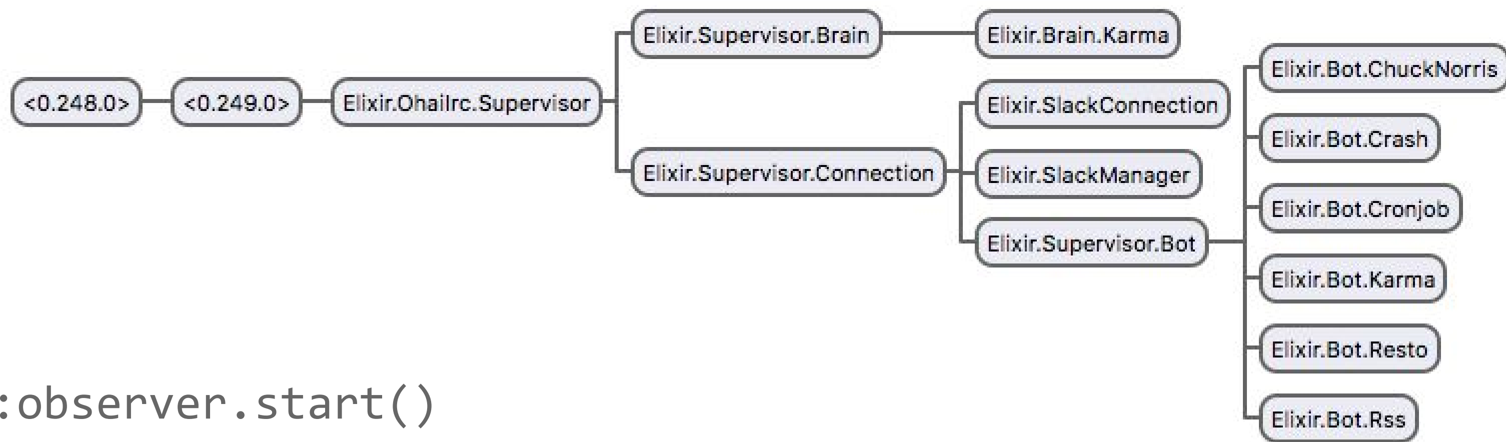
https://github.com/m1dnight/slackbot

Dependencies

- Slack connection (https://hex.pm/packages/slack)
- JSON parser (https://hex.pm/packages/poison)
- Date/Time (https://hex.pm/packages/timex)
- RSS Feeds (https://hex.pm/packages/feeder_ex)

Architecture

All components are grouped in “Supervisor Trees”




```
iex>:observer.start()
```

The Slack Behaviour

- 3 callbacks
  - handle_connect/2
  - handle_event/3
  - handle_close/3

On connect

Any Slack activtiy

On disconnect

- Not a GenServer, not supervisable.
  - But we want to supervise it!

The Slack Behaviour

```elixir
defmodule SlackLogic do
  use GenServer
  use Slack
  def handle_connect(slack, state) do
    SlackManager.notify(:connected)
    {:ok, state}
  end

  def handle_event(message = %{type: "message", text: text}, slack, state) do
    SlackManager.notify(message)
    {:ok, state}
  end

  def handle_close(_reason, _slack, state) do
    SlackManager.notify(:disconnected)
    {:ok, state}
  end
end
```

SlackManager - Publish/Subscribe

```
defmodule SlackManager do
  use GenServer
  defmodule State do
    defstruct client: :nil, handlers: MapSet.new(), token: :nil, aliases: %{}
  end
  def start_link(client,token) do
    GenServer.start_link(__MODULE__, [client,token], name: __MODULE__)
  end
  def init([client,token]) do
    {:ok, %State{client: client, token: token}}
  end

  def handle_cast({:notify, m}, state) do
    for handler <- state.handlers, do: send(handler, m)
    {:noreply, state}
  end
  ...
  def notify(m) do
     GenServer.cast(SlackManager, {:notify, m})
  end
```

Thanks, Supervisor

Assume existence of a process named "SlackManager"

Storage

- Plain text files with Erlang terms
- Actor representing state
- Seperate supervision tree

```elixir
defmodule Brain.Karma do
  use GenServer
  def increment(subject, amount \\ 1) do
    GenServer.call __MODULE__, {:change, subject, amount}
  end
  def decrement(subject, amount \\ -1) do
    GenServer.call __MODULE__, {:change, subject, amount}
  end
  def get(subject) do
    GenServer.call __MODULE__, {:get, subject}
  end
```

Storage

```
  def handle_call({:get, subject}, _from, state) do
    {^subject, current_karma} = List.keyfind(state, subject, 0, {subject, 0})
    {:reply, current_karma, state}
  end

  def handle_call({:change, subject, amount}, _from, state) do
    {^subject, current_karma} = List.keyfind(state, subject, 0, {subject, 0})
    new_karma = current_karma + amount
    new_state = List.keystore(state, subject, 0, {subject, new_karma})
    content = new_state
    |> Enum.map(&[:io_lib.print(&1) | ".\n"])
    |> IO.iodata_to_binary
    File.write(data_backup_file(), content)
    {:reply, new_karma, new_state}
  end
end
```

Storage

```
def increment(subject, amount \\ 1) do
  GenServer.call __MODULE__, {:change, subject, amount}
end

def decrement(subject, amount \\ -1) do
  GenServer.call __MODULE__, {:change, subject, amount}
end

def get(subject) do
  GenServer.call __MODULE__, {:get, subject}

end
```

Plugins (and also a first macro!)

- Define a custom behaviour to reduce boilerplate code

```
defmodule Plugin do

  # Each Plugin should implement an on_message function.
  @callback on_message(message :: term, channel :: term) :: any

  # Optional callback to execute when the plugin starts.
  @callback initialize() :: any
...
```

Plugins (and also a first macro!)

- Define a custom behaviour to reduce boilerplate code

```
defmacro __using__(_) do
    quote location: :keep do
      @behaviour Plugin
      use GenServer
      def init(args) do
        SlackManager.add_handler self()
        {:ok, args}
      end
      def handle_info(message = %{type: "message", text: text}, state) do
        reply = on_message(text, message.channel)
        ...
      end
```

Plugins (and also a first macro!)

- Define a custom behaviour to reduce boilerplate code

```
def initialize(), do: :ok
defoverridable initialize: 0
```

A Plugin

```
defmodule Bot.ChuckNorris do
  use Plugin
  @url 'http://api.icndb.com/jokes/random'
  def on_message(<<"joke?"::utf8, _::bitstring>>, _channel) do
    j = joke()
    case j do
      {:error, e} -> IO.puts "Error getting joke #{e}"
                     {:noreply}
      {:ok, text} -> {:ok, "#{text}"}
    end
  end
  #Catch-all
  def on_message(_m, _channel) do
    {:noreply}
  end
end
```

Thanks!

- Elixir is built on a battle-tested virtual machine
- Pattern matching, reduces a lot of code
- BEAM offers you, with little to no effort:
    - Distribution
    - Scalability
    - Reliability
    - More-ities
- OTP offers you modularity by construction (if you follow the unwritten rules)
- Slackbot is awesome

Some ideas..

- Interconnect all Slackbots and obtain world domination
- Use the Erlang ETS table
- Use macros to remove even more boilerplate from Plugins
- Use a database for the bot’s brain

  https://hexdocs.pm/ecto/Ecto.html
- Let it proxy cleverbot

  http://www.cleverbot.com/api
- Patches welcome!