AtomVM

About me (Davide Bettio)

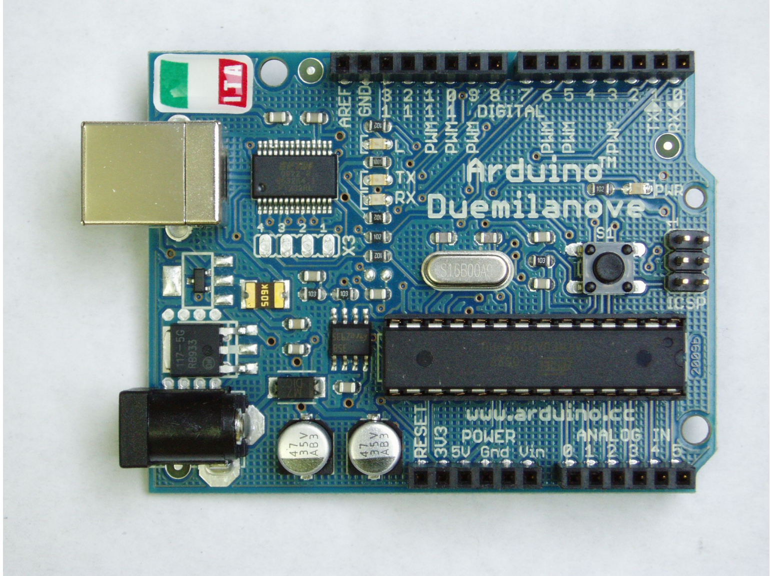
https://github.com/bettio/ I davide@uninstall.it I https://uninstall.it/

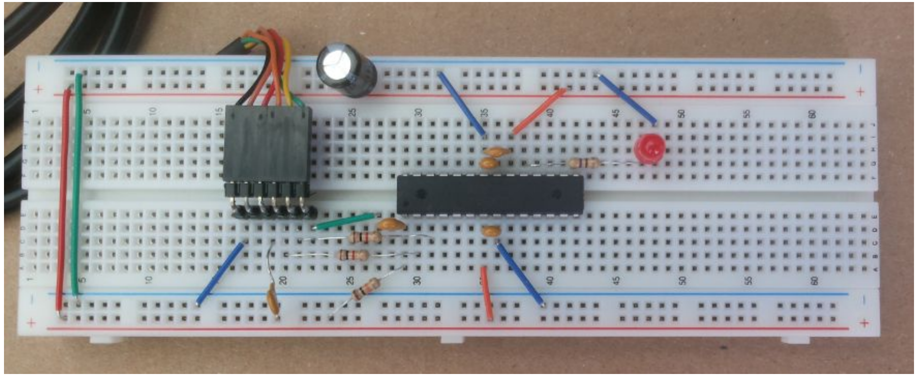
- Tinker with hardware and embedded systems since 2004.
- Long-time open-source dev (since ~2005 contributed to KDE Plasma and others).
- Fell in love with Elixir in 2017, while creating Astarte Platform.
- Started the AtomVM project in 2017
- I love hiking!

So... What's AtomVM?

Once Upon a Time, the Arduino

- The pioneer of physical computing devices
- Simple to assemble and develop
- Cheap (arduino board ~20 €, IC: < 2 €)
- Very limited, yet so powerful





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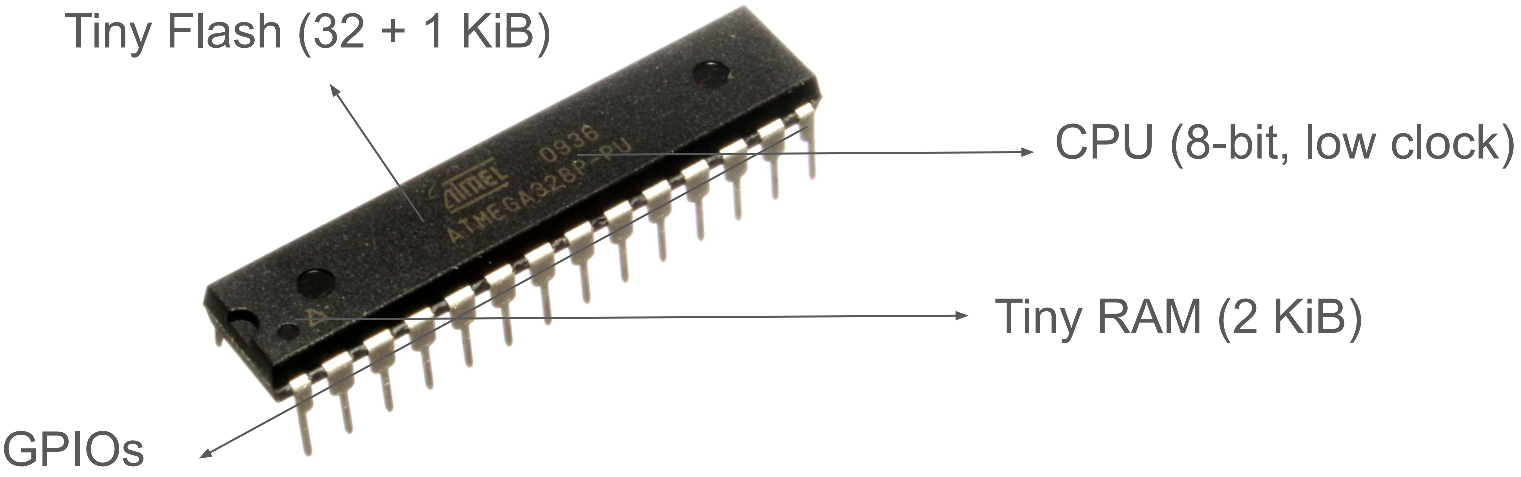
Classic MCU Anatomy (e.g., ATMega328P)

A small computer on a chip:



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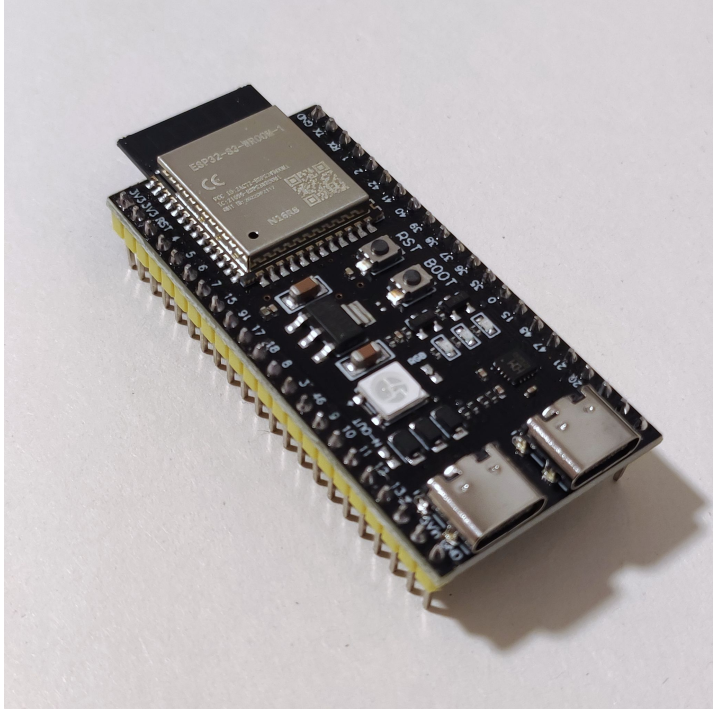
Modern MCU: ESP32 Example

ESP32:

- Cost < 5 €
- Dual Core @ 240MHz
- RAM: ~500KB - 8MB
- Flash: 4MB - 16MB
- Connectivity: WiFi, Bluetooth, etc.
- Lots of GPIOs & integrated peripherals
- Low Power / Battery-friendly



Powerful, But Still...Different

- Massive leap from classic MCUs
- Still resource-constrained vs. PCs/Servers
  - KB/MB RAM, not GB
  - No OS (or RTOS)
  - Development: Mostly C / C++

https://www.reddit.com/r/PallasCats/comments/1d8j3jd/bol/

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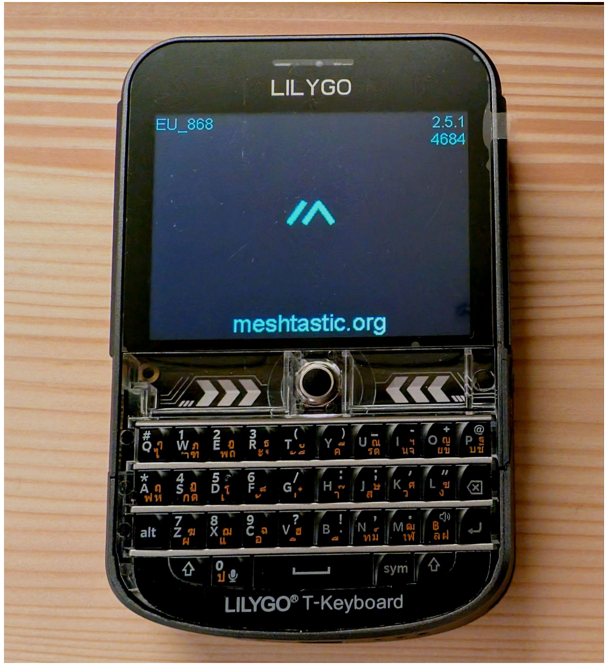
The C/C++ Experience on MCUs

- Concurrency? Manual, tricky.
- Binary parsing? Boring & dangerous.
- Async? Callback hell, anyone?
- Memory?

The Intricacies of Embedded Communication: LoRa

- LoRa: Long-Range radio, raw bytes to CPU
- Need to implement: routing, security, mesh
- Meshtastic parses them in C++
  - C++: One wrong move... 💣



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Clarity in Complexity for LoRa Packets

```elixir
def parse(
    <<dest::little-unsigned-32, src::little-unsigned-32, pkt_id::little-unsigned-32,
      hop_start::size(3), via_mqtt::size(1), want_ack::size(1),
      hop_limit::size(3), channel_hash::8, _padding::16, encrypted_data::binary>>) do
  {:ok, %{dest: dest, src: src, packet_id: pkt_id,
          hop_start: hop_start, via_mqtt: int_to_bool(via_mqtt), want_ack: int_to_bool(want_ack),
          hop_limit: hop_limit, channel_hash: channel_hash, encrypted_data: encrypted_data}}
end

def parse(_), do: {:error, :failed_meshtastic_parse}

def decrypt(%{src: src, packet_id: pkt_id, encrypted_data: enc_data} = packet, key) do
    iv = <<pkt_id::little-unsigned-64, src::little-unsigned-32, 0::32>>

    decrypted = :crypto.crypto_one_time(:aes_128_ctr, key, iv, enc_data, false)
    packet
    |> Map.put(:data, decrypted)
    |> Map.delete(:encrypted_data)
end

defp int_to_bool(0), do: false
defp int_to_bool(1), do: true
```

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Projects like Meshtastic couldn’t leverage these advantages on such microcontrollers. **The standard BEAM VM wasn’t designed for environments with only ~500 KiB of available RAM.**

What if we could bring *somehow* the safety, concurrency, and productivity of the BEAM ecosystem to these tiny devices?

AtomVM

To the Rescue

AtomVM, A lightweight virtual machine designed to run compiled Erlang, Elixir and Gleam code on microcontrollers with limited resources.

- Key Trade-offs:
  - Memory First: RAM & Flash are precious
  - Portability: New targets in hours, not days
  - Flexible Requirements: Adaptable core

Mission accomplished: it worked

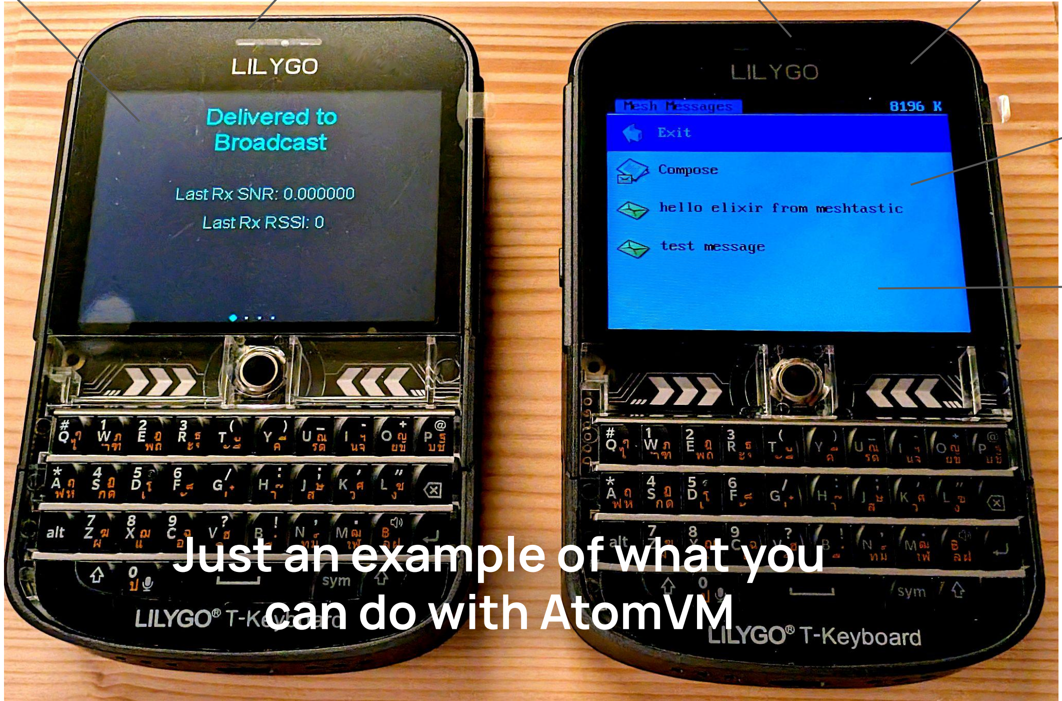
Original firmware
in C++

Battery powered
CPU: ESP32-S3
Radio: LoRa

This simple project in Elixir
runs on AtomVM

Display managed using **AtomGL** component.
UI is written in Elixir

Runs a pure Erlang/Elixir app:
(github.com/bettio/pocketOS/)



Delivered to Broadcast

Last Rx SNR: 0.000000

Last Rx RSSI: 0

hello elixir from meshtastic

test message

Just an example of what you can do with AtomVM

Let’s do our simple Hello World Project

What you Need / Suggested Hardware

Option 1: **Espressif**

- **ESP32 / ESP32-S2, ESP32-S3 DevKit C** → **Wifi, Bluetooth**, up to **8 MiB** of PSRAM
- **ESP32-C2/C3** → Wifi, Bluetooth, up to ~512 KiB or RAM, RISC-V CPU
- **ESP32-C6** → Wifi, Bluetooth, **Thread, ZigBee**, RISC-V CPU
- And many more... (ESP32-H2, -C5, -P4) with different features

Disclaimer: Do not buy ESP8266 and other ancient devices pre-ESP32

Idea: search for fancy devboards, or cheap ones, like the “cheap yellow display”

AtomVM

What you Need / Suggested Hardware

Option 2: **Raspberry Pi Pico**

- Pico 1/1W (RP2040) → **264 KiB of RAM,** dual core @ 133 MHz+, 2 MiB+ flash
- Pico 2/W (RP2350) → **512 KiB of RAM,** dual core @ 150 Mhz, 4 MiB+ flash
- **The 'W' models include Wi-Fi + Bluetooth**
- What's cool? Peripherals & **Programmable I/O (PIO)**

Note: Raspberry Pi Pico ≠ "classic" Raspberry Pi or Raspberry Pi Zero

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What you Need / Setup

- Minimal hardware setup: just a USB cable (that’s it)
- A serial terminal app (like `minicom` on Linux/macOS or `PuTTY` on Windows)
  - This is how you’ll see all the debug, error, and info messages from your device
- Your favorite Erlang/Elixir/Gleam setup

Big Disclaimer

Source: https://manulization.com/manuls/magellan.html

- Heads up: AtomVM is still pre-v1.0, which means APIs are not yet stable
- We will break APIs, but the core concepts will remain the same
- The code here might not work forever, but we keep the official documentation and examples up-to-date

See also: https://doc.atomvm.org/latest/UPDATING.html

AtomVM

Next Step: `exatomvm`

- Add `{:exatomvm, github: "AtomVM/exatomvm", runtime: false}` to `mix.exs`
- It provides you a number of mix tasks to build & flash your project
- Optional: add `{:pythonx, "~> 0.4.0", runtime: false}`, so you can just flash your app without any additional toolchain or SDK
- On ESP32: **`mix atomvm.esp32.install`** `(downloads a pre-built binary)`

Erlang users: https://github.com/atomvm/atomvm_rebar3_plugin

Gleam users: https://github.com/gleam-eensy

AtomVM

Configuring mix.exs

Just add an `atomvm` section to mix.exs project function:

```
def project do
    [...]
    atomvm: [
      start: Blink, # the module with our start/0 entry point function
      flash_offset: 0x210000
    ]
end
```

The Physical Computing Hello World

```elixir
defmodule Blink do
  @pin 2
  def start() do
      GPIO.set_pin_mode(@pin, :output)
      loop(:high)
  end
  defp loop(level) do
      GPIO.digital_write(@pin, level)
      Process.sleep(200)
      loop(toggle(level))
  end
  defp toggle(:high), do: :low
  defp toggle(:low), do: :high
end
```

See also:
https://github.com/atomvm/AtomVM/tree/main/examples

AtomVM

What’s a GPIO?

- **GPIO** stands for **G**eneral **P**urpose **I**nput/**O**utput.
- Think of them as simple digital pins that can be either an input or an output
- They can be set to high (e.g., `3.3V`) or low (`0V` / Ground).

For our LED, this means it’s either fully on or fully off. No fading.

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The AtomVM Workflow

- Add `{:exatomvm, github: "AtomVM/exatomvm", runtime: false}` to `mix.exs` ✓
- Write Elixir (like always!) ✓
- (Behind the scenes: compile, like always!)
- (Behind the scenes: pack, `mix.atomvm.packbeam → myapp.avm`)
- **Flash, run one command: (e.g. `mix atomvm.esp32.flash`)**

Remember: AtomVM runs unmodified BEAM file, so any language that runs on the BEAM, will run on AtomVM.

AtomVM

Demo

HONESTLY I WILL NOT DO A BLINKING LED DEMO. TRUST ME IT WORKS. I WILL NOT EVEN TRY SHOWING A MICROSCOPIC LED TO THE AUDIENCE. IF I BRING BOARDS AND ELECTRONICS ON A AIRPLANE I MIGHT BE MISIDENTIFIED AS A TERRORIST. DEMOS ALWAYS FAIL ANYWAY.

AtomVM

Time for `minicom -D /dev/ttyACM0`

- After flashing, use a serial monitor (like minicom) to read `IO.puts` and `IO.inspect` output
- Don’t run the serial monitor and the flasher at the same time
- It may require some configuration

Circuits Pro-tips

Don’ts

1. **Never mess with “GND”** (the ground): if you connect GND pin to something that is not ground/0V you are likely going to fry your device
2. **Respect polarity:** components like LEDs and some capacitors have positive and negative sides: connecting them backward = ☠️
3. **Don’t mix voltage levels**: sending 5V into a 3.3V pin can permanently damage the chip unless the pin is explicitly *'5V tolerant'*
4. **Always connect an antenna**: before powering on a radio. Without it, the transmitter can be damaged

Do: **Double-check all your connections before powering up your device!**

AtomVM

Handling a Button Press

Goal: We want to know when a button is pressed

- The naive way is "polling": constantly looping to check the button's GPIO pin
  - The problem? This keeps the CPU busy doing nothing and drains the battery. This is called "busy-waiting"

- A better way: Interrupts
  - A hardware interrupt tells the CPU to pause its current task and handle something important *right now*
  - In AtomVM, we translate these hardware interrupts into standard Elixir messages

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Interrupts in Elixir

First, we configure the GPIO as an input and tell it to trigger an interrupt on a 'falling edge' (when the button is pressed):

```
:gpio.set_direction(gpio, gpio_num, :input)

:gpio.set_int(gpio, gpio_num, :falling)
```

The **hardware event is safely delivered to your process’s mailbox as a message**. No callbacks, no polling—just the actor model you already know and love. e.g., let’s add to our GenServer:

```
def handle_info({:gpio_interrupt, gpio_num}, state) do

    IO.puts "Button pressed"

    {:noreply, state}

end
```

Source: https://www.flickr.com/photos/tambako/31556104335/in/photostream/

Great, I’m blinking an LED and reading a button. Now what?

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Peripherals!

- Connecting to the outside world: peripherals!
- Usually, a *bus* lets you connect multiple devices to the same set of GPIO pins
- Many flavors
  - **I2C** → 2 wires, synchronous, slow-to-medium speeds
  - **SPI** → 4-wire bus (or more), synchronous, faster than I²C, good for displays
  - **UART** → 2-wire bus, point-to-point connection. TL;DR: a serial port
- Most sensors, displays, and other modules use one of these standard communication protocols (or "buses")

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Native vs Elixir Components

- AtomVM APIs (`spi`, `i2c`, `gpio`) let you build libraries for **complex peripherals in pure Elixir/Erlang (no C required).**

- High-performance or very low-level hardware access?
  - Use **Native components (NIFs and Ports)**, just like the regular BEAM
  - The catch: using native components requires a custom AtomVM build using the device's SDK (like the ESP-IDF)

AtomVM

Displaying stuff: AtomGL

- A native component for rendering to a display
- Displays any list of items:

```
{:text, 16, 16, :default16px, 0xFFFFFF, 0x404040, title},
{:image, div(320 - 64, 2), div(240 - 64, 2), 0x404040, error_image}
```

- There is an additional `avm_scene` library that provides some scaffolding for managing displayed scene, using a `gen_server` like approach:

```
def handle_info(:show_foo, %{width: width, height: height} = state)
do
    {:noreply, state, [{:push, items}]}
end
```

See also: https://github.com/atomvm/atomgl

What about I in IoT?

- There is a handy `network` module
- AtomVM has support for `gen_tcp`, `gen_udp` and `socket`
- `http_server` and `ahttp_client` modules
- `mdns` for finding your device on the network

See also: https://doc.atomvm.org/latest/network-programming-guide.html

Setting up Wi-Fi & Handling HTTP Requests

```
Config = [
  {sta, [
    {ssid, <<"myssid">>},
    {psk, <<"mypsk">>},
    {connected, fun() -> self() ! net_up end},
    {disconnected, fun() -> self() ! net_down end}
  ]}
],
network:start(Config)
```

```
router = [
  {"*", __MODULE__, []}
]
:http_server.start_server(8080, router)
[...]
def handle_req("GET", [], conn) do
  body =
    "<html>\n" <> [...]
  :http_server.reply(200, body, conn)
end
```

AtomVM has some additions/differences

Compared to the regular BEAM, AtomVM has some extensions to the standard BEAM (usually prefixed with atomvm or avm), e.g.:

- `:atomvm.read_priv/2` →reads a binary file stored in a loaded .avm file
- `:atomvm.posix_*` → posix functions, they mimic unistd.h ones

.beam files are packed into .avm files, that are designed to be written directly to flash memory (no filesystem needed).

(BTW: they all start with `#!/usr/bin/env AtomV` →

next idea: making startup-time-free CLI tools with AtomVM ;))

AtomVM

Beyond

Popcorn

Popcorn is a library that allows you to run client-side Elixir in browsers, with JavaScript interoperability.

https://popcorn.swmansion.com/

Popcorn: How Does it Work?

- **AtomVM itself is compiled to WebAssembly** (emscripten platform), apps are still compiled as beam files with the **regular Elixir compiler**
- Small footprint: the VM is ~200 KiB gzipped
- Popcorn gives you:
  - Tooling: `mix popcorn …`
  - An easy-to-use library for JavaScript interoperability
  - The *full* Elixir standard library, not the reduced version used on MCUs

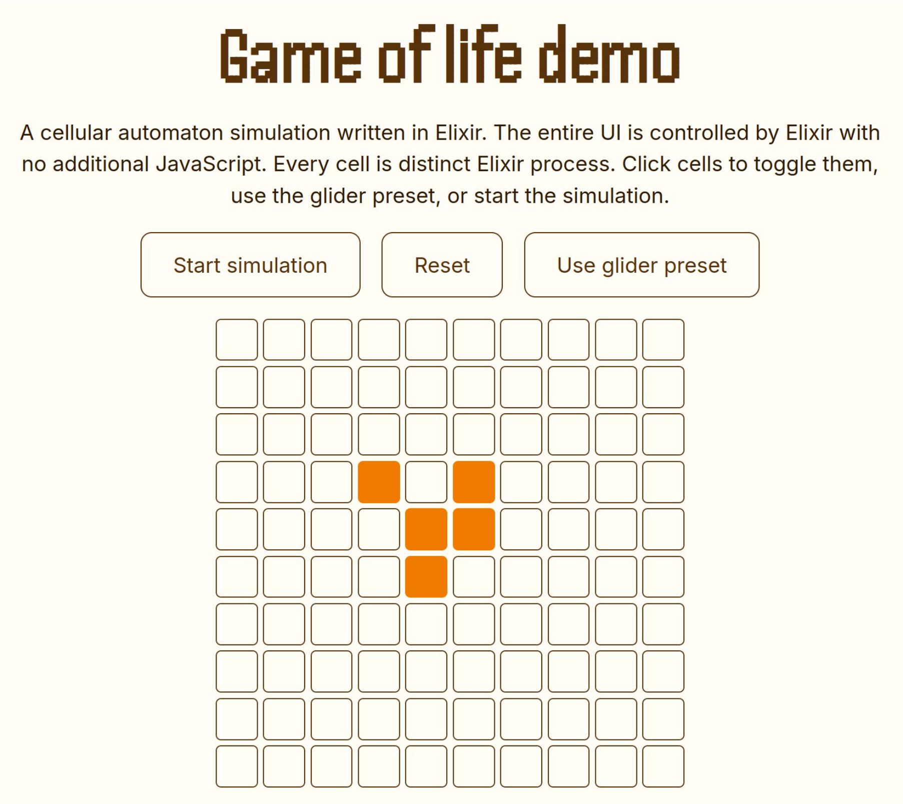
TL;DR: It’s still AtomVM, just with batteries included for the browser

AtomVM

Wise Manul:

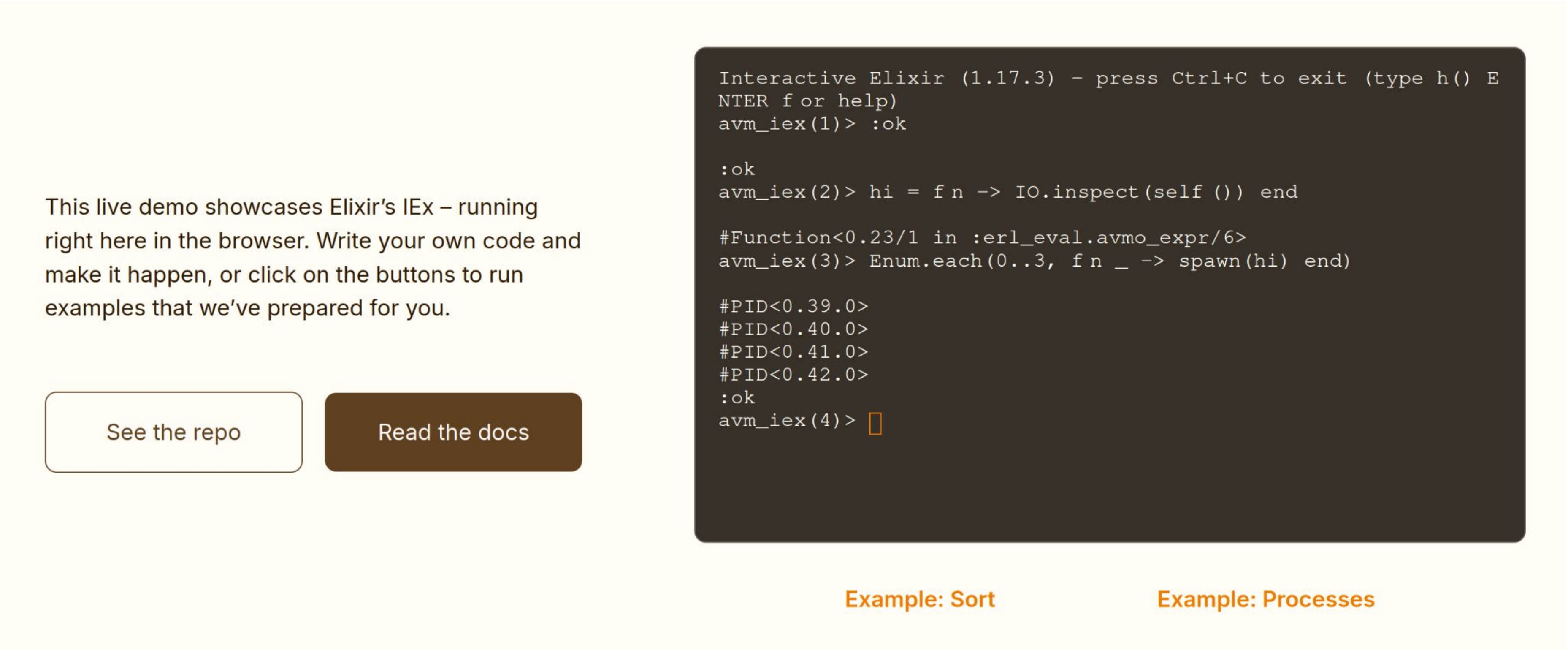
Simple as:

```
def deps do
  [
    {:popcorn, "~> 0.1.0"}
  ]
end
```



Game of life demo

A cellular automaton simulation written in Elixir. The entire UI is controlled by Elixir with no additional JavaScript. Every cell is distinct Elixir process. Click cells to toggle them, use the glider preset, or start the simulation.

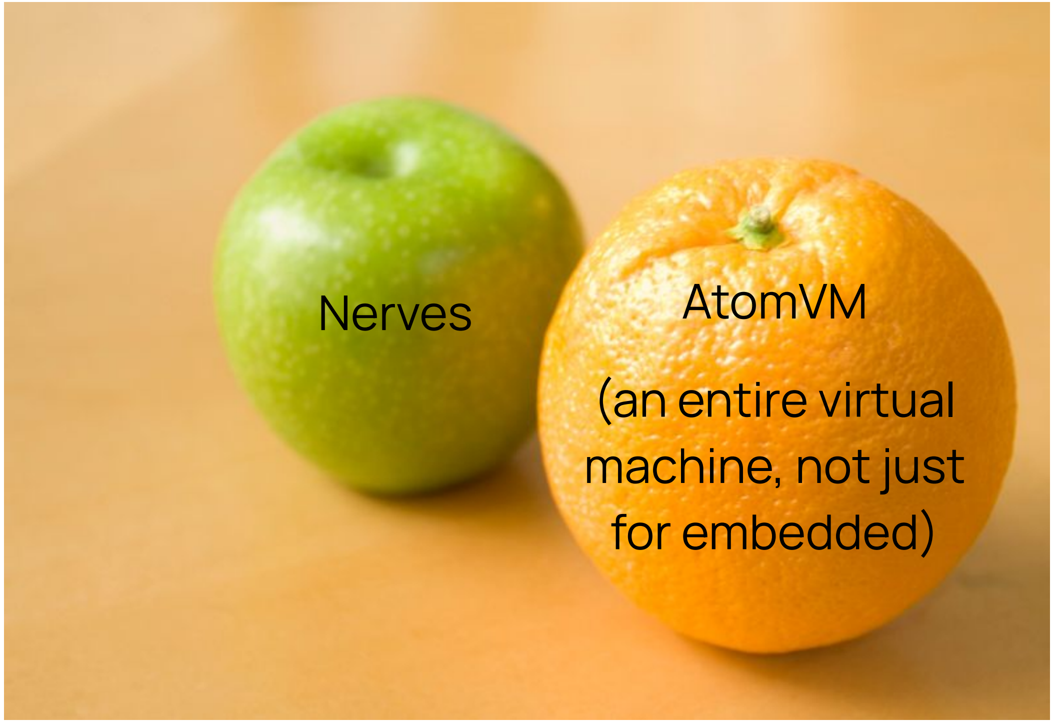


This live demo showcases Elixir's IEx – running right here in the browser. Write your own code and make it happen, or click on the buttons to run examples that we've prepared for you.

```
Interactive Elixir (1.17.3) - press Ctrl+C to exit (type h() E
NTER f or help)
avm_iex(1)> :ok

:ok
avm_iex(2)> hi = f n -> IO.inspect(self ()) end

#Function<0.23/1 in :erl_eval.avmo_expr/6>
avm_iex(3)> Enum.each(0..3, f n _ -> spawn(hi) end)

#PID<0.39.0>
#PID<0.40.0>
#PID<0.41.0>
#PID<0.42.0>
:ok
avm_iex(4)>
```

Closing Words on AtomVM

Comparison with Nerves



https://en.wikipedia.org/wiki/Apples_and_oranges#/media/File:Apple_and_Orange_-_they_do_not_compare.jpg

Let's compare apples and oranges anyway.

AtomVM on MCUs, TL;DR:

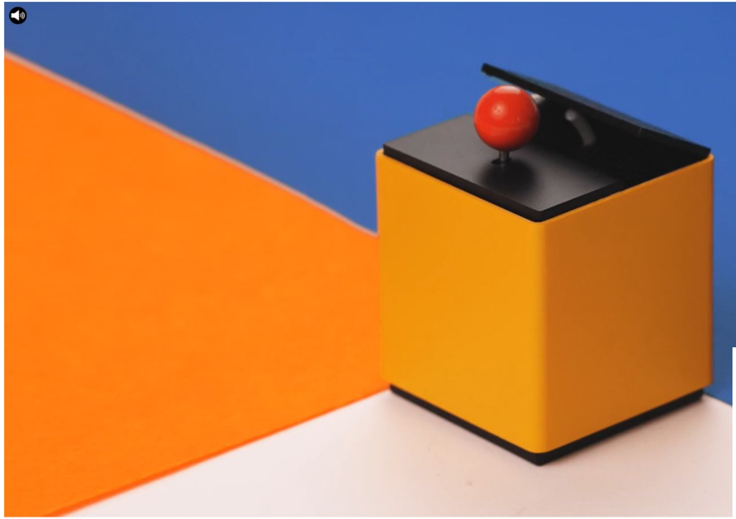
- Hello world footprint: 512 KiB of flash, 32 KiB of RAM
- Perfect for cheap low power devices
- ...

AtomVM

la machine

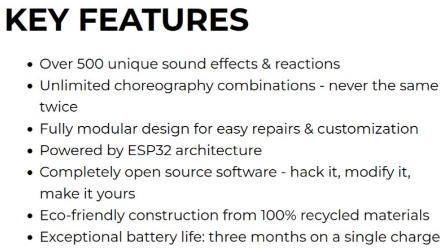
by multiplié

The Useless Box : Reloaded



- AtomVM powered
- ESP32-C3
- 32-bit RISC-V single-core @ 160 MHz 400 KiB of SRAM
- 5 µA in deep sleep !

- la machine **code is in Erlang**
- uses `atomvm_esp_adf` component for **playing audio** from Erlang code (thanks Paul)



KEY FEATURES

- Over 500 unique sound effects & reactions
- Unlimited choreography combinations - never the same twice
- Fully modular design for easy repairs & customization
- Powered by ESP32 architecture
- Completely open source software - hack it, modify it, make it yours
- Eco-friendly construction from 100% recycled materials
- Exceptional battery life: three months on a single charge

What’s Next

New: Erlang Distribution and JIT (thanks Paul), Big Integers and other 40+ additions.

Soon:

- Bitstrings

Future:

- More devices & peripherals (Zephyr devices, Bluetooth, Zigbee/Thread, etc…)
- Even better tooling & DevX
- Stable APIs (path to 1.0)

AtomVM

Releases

- **Stable Release: v0.6.6**: https://github.com/atomvm/AtomVM/releases
    - Up to OTP-27, OTP-28 support has not been backported yet
    - Pre-built binaries available
    - Well tested, focused on stability
- Development branch: main
    - https://github.com/atomvm/AtomVM/tree/main
    - Moving target, still pretty high quality
    - Includes Erlang Distribution, JIT and big integers

Contributing

- Any kind of contribution is welcome (artists included)
- Feedback and issues are valuable
- Code contributions in C, Erlang, Elixir and Gleam are appreciated

(Honestly I think we can do better on the Gleam side, so I'd like to hear more from Gleam folks!)

Join Us

https://atomvm.org/

Discord: https://discord.gg/QA7fNjm9Nw

Telegram: https://t.me/atomvm

Documentation: https://doc.atomvm.org/

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