Marimo

Marimo

From Wikipedia, the free encyclopedia

Marimo[a] (also known as **Cladophora ball**, **moss ball**, **moss ball pet**, or **lake ball**) is a rare growth form of ***Aegagropila linnaei*** (a species of filamentous green algae) in which the algae grow into large green balls with a velvety appearance.

The species can be found in a number of lakes and rivers in Japan and Northern Europe.[1] Colonies of marimo balls are known to form in Japan and Iceland, but their population has been declining.[2]

Classification and name [edit]

Marimo were first described in the 1820s by Anton E. Sauter, found in Lake Zell, Austria. The genus *Aegagropila* was established by Friedrich T. Kützing (1843) with *A. linnaei* as

Marimo

Marimo in Lake Akan in Japan

Scientific classification

Marimo

Reactive, Git-friendly, Notebooks

🚀 **batteries-included:** replaces jupyter, streamlit, jupytext, ipywidgets, papermill, and more

https://marimo.io/

What does it try to solve?

- https://leomurta.github.io/papers/pimentel2019a.pdf

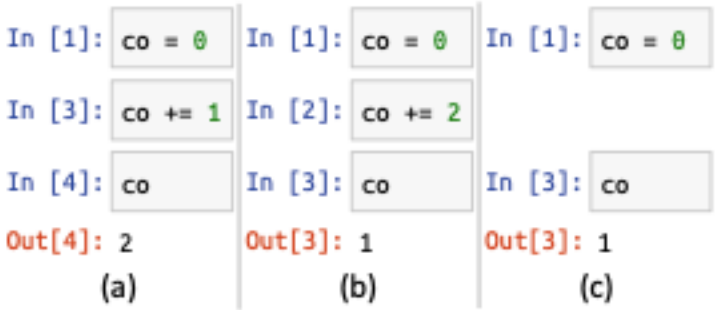

Fig. 2. Three types of Hidden States: (a) Re-execution; (b) edited cell; (c) removed cell.

Fig. 13. Distribution of cell reproducibility.

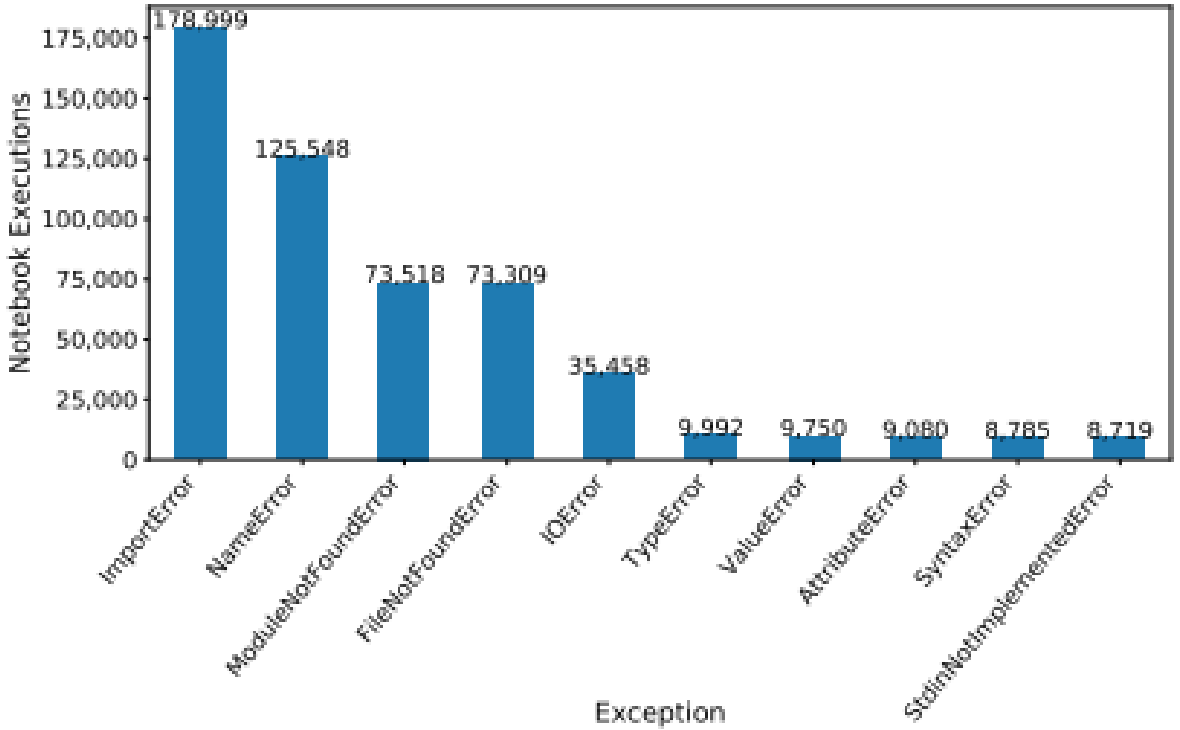

Fig. 12. Top 10 most common exceptions.

What is another problem?

notebooks/logo_checks_pipeline.ipynb

```
@@ -4,11 +4,10 @@
    "cell_type": "code",
    "execution_count": null,
    "id": "initial_id",
-   "metadata": {
-    "collapsed": true
-   },
+   "metadata": {},
    "outputs": [],
    "source": [
+    "import urllib.parse\n",
     "from temporalio.client import Client\n",
     "from utils.pdf.annotations import process_pdf_annotations\n",
     "from utils.storage.minio import MinioClient\n",
@@ -26,7 +25,6 @@
    "outputs": [],
    "source": [
     "DOC_NUMBER = \"US-KEY-135915\"\n",
-    "# DOC_NUMBER = \"US-VER-04816\" # Large document, 100MB\n",
     "PM_SESSION = \"\""
    ]
   },
@@ -76,7 +74,6 @@
     "    \"version_modified_date\": metadata[0][\"version_modified_date\"],\n",
     "    \"product_family\": metadata[0][\"product_family\"],\n",
```

And what if I want to run it as a script?

Papermill or `python -m jupyter nbconvert --to python XYZ.ipynb` + argparse

```
$ papermill local/input.ipynb s3://bkt/output.ipynb -p alpha 0.6 -p l1_ratio 0.1
```

But ...

```
#parameters
a = 1
twice = a * 2
```

```
print("a =", a, "and twice =", twice)
```

when executed with `papermill note.ipynb -p a 9`, the output will be `a = 9 and twice = 2` (not `twice = 18`).

And what about interactivity?

IntSlider

[2]:
```
widgets.IntSlider(
    value=7,
    min=0,
    max=10,
    step=1,
    description='Test:',
    disabled=False,
    continuous_update=False,
    orientation='horizontal',
    readout=True,
    readout_format='d'
)
```

Color picker

[35]:
```
widgets.ColorPicker(
    concise=False,
    description='Pick a color',
    value='blue',
    disabled=False
)
```

Exercise: What would be the solution?

- Any suggestions? Ideas?
  - Not using JSON-like format
  - Rerun everything with every change
  - …

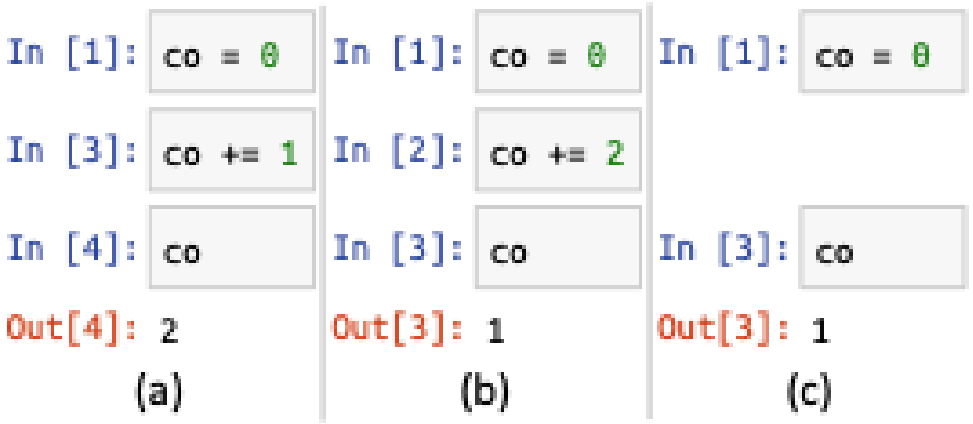

Fig. 2. Three types of Hidden States: (a) Re-execution; (b) edited cell; (c) removed cell.

Showcase (folder 01)

- Reactivity
- Python frontend
- Git-friendly
- https://docs.marimo.io/guides/coming_from/#5-layouts

- “Decorators” to rescue (see created file)

How does it try to solve that?

- marimo **statically** analyzes each cell (i.e., without running it) to determine its
  - references, the global variables it reads but doesn't define;
  - definitions, the global variables it defines.
- It then forms a directed acyclic graph (DAG) on cells
- Drawback of static approach:
  - It is not working with complex objects (for example, attributes of the instance)
  - Mutation of the objects (append to the list)
  - → do it in one cell, or do not mutate (create new object)
- https://docs.marimo.io/guides/best_practices/

How does it try to solve that?

- marimo **stati** ut running it) to determine its
  - references, define;
  - definitions,
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- Drawback of
  - It is not worl attributes of the instance)
  - Mutation of
  - → do it in or ect)
- https://docs.

AST – Abstract Syntax trees (folder 02)

```
49  def ast_parse(
50      contents: str, suppress_warnings: bool = True, **kwargs: Any
51  ) -> ast.Module:
52      if not suppress_warnings:
53          return cast(typ=ast.Module, val=ast.parse(source=contents, **kwargs))
54      with warnings.catch_warnings():
55          warnings.simplefilter(action="ignore", category=SyntaxWarning)
56          # The SyntaxWarning is suppressed only inside this `with` block
57          return cast(typ=ast.Module, val=ast.parse(source=contents, **kwargs))
```

https://docs.python.org/3/library/ast.html

AST – Abstract Syntax trees

```
Module(
    body=[
        FunctionDef(
            name='_',
            args=arguments(),
            body=[
                Assign(
                    targets=[
                        Name(id='a', ctx=Store())],
                    value=Constant(value=1)),
                Return(
                    value=Tuple(
                        elts=[
                            Name(id='a', ctx=Load())],
                        ctx=Load()))]),
        FunctionDef(
            name='_',
            args=arguments(
                args=[
                    arg(arg='a')]),
            body=[
                Assign(
```

02/run_ast.py

https://docs.python.org/3/library/ast.html

AST -> Graphs ->

```
class ScopedVisitor(ast.NodeVisitor):
```

```
class DirectedGraph:        Initial commit, Akshay Agrawal (2 years ago)
    # Nodes in the graph
    cells: dict[CellId_t, CellImpl] = field(default_factory=dict)

    # Edge (u, v) means v is a child of u, i.e., v has a reference
    # to something defined in u
    children: dict[CellId_t, set[CellId_t]] = field(default_factory=dict)

    # Reversed edges (parent pointers) for convenience
    parents: dict[CellId_t, set[CellId_t]] = field(default_factory=dict)
```

class ast.**NodeVisitor**

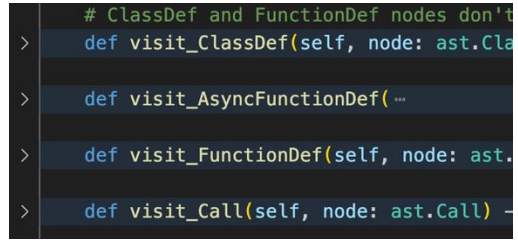
A node visitor base class that walks the abstract syntax tree and calls a visitor function for every node found. This function may return a value which is forwarded by the `visit()` method.

This class is meant to be subclassed, with the subclass adding visitor methods.

https://docs.python.org/3/library/ast.html#ast.NodeVisitor

```
v: Unknown = ScopedVisitor("cell_" + cell_id)
v.visit(module)
```

Take module (code in the cell) and visit each node in AST ->




```
nonlocals: set[@Todo] = {name for name in v.defs if not is_local(name)}
temporaries: Unknown = v.defs - nonlocals
variable_data: dict[@Todo, @Todo] = {
    name: v.variable_data[name]
    for name in nonlocals
    if name in v.variable_data
}
```

Get the output for the piece of code

Now v contains:
- v.defs: set of defined variables
- v.refs: set of referenced variables
- v.variable_data: metadata about each variable

```
return CellImpl(
    # keyed by original (user) code, for cache lookups
    key=code_key(code=code),
    code=code,
    mod=original_module,
    defs=nonlocals,
    refs=v.refs,
    sql_refs=v.sql_refs,
    temporaries=temporaries,
    variable_data=variable_data,
```

Get the internal representation of intput/output – with references

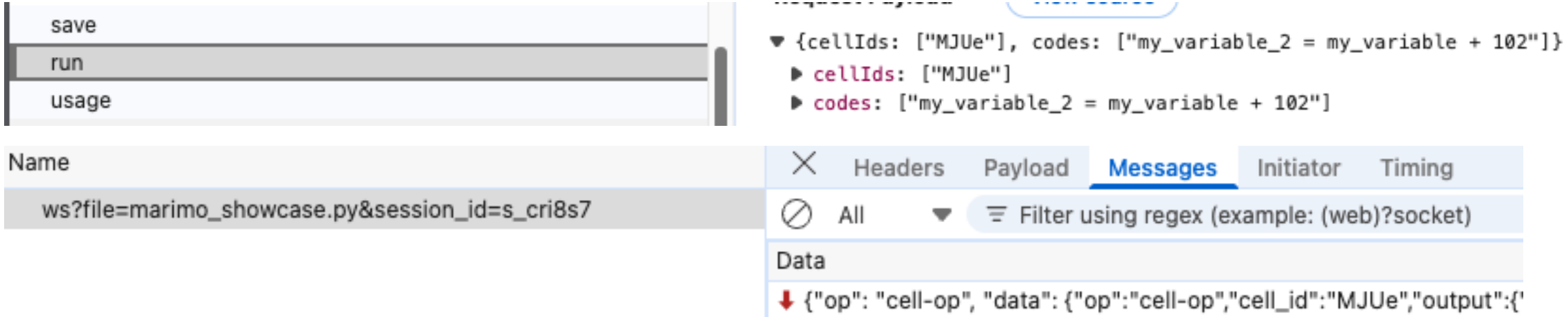
body = bytecode

So we have a graph. Now what? Need to show it

- Exercise number 2 ☺
- Options? What do you think?
  - Infinite loop

How to create responsive UI? -> Websockets

- Websocket (on top of https://starlette.dev/ - light ASGI used by FastAPI)
- Frontend listen for updates on each cell
- # Frontend send a change to backend (to the queue)
- # Backend will execute cell (with a Graphs of dependency in mind)
- # Backend will send an update to frontend



Backend

```python
@router.websocket("/ws")
async def websocket_endpoint(websocket: WebSocket) -> None:
    # 1. Authentication check
    if app_state.enable_auth and not validate_auth(websocket):
        await websocket.close(WebSocketCodes.UNAUTHORIZED, "MARIMO_UNAUTHORIZED")
        return

    # 2. Extract query parameters
    session_id = SessionId(raw_session_id)
    file_key = app_state.query_params(FILE_QUERY_PARAM_KEY)
    kiosk = app_state.query_params(KIOSK_QUERY_PARAM_KEY) == "true"

    # 3. Create WebsocketHandler
    await WebsocketHandler(
        websocket=websocket,
        manager=app_state.session_manager,
        session_id=session_id,
        file_key=file_key,
        kiosk=kiosk,
        ...
    ).start()
```

```python
def write_operation(self, op: MessageOperation) -> None:
    self.message_queue.put_nowait(serialize_kernel_message(op))
```

```python
v: Unknown = ScopedVisitor("cell_" + cell_id)
v.visit(module)
```

Frontend

```typescript
// In useWebSocket.tsx
const socket: IReconnectingWebSocket =
  isWasm() ? new PyodideWebsocket(PyodideBridge.INSTANCE)
  : options.static ? new StaticWebsocket()
  : new ReconnectingWebSocket(rest.url, undefined, {
      maxRetries: 10,
      startClosed: true,
      connectionTimeout: 10_000,
    });
```

```typescript
onMessage: (event: WebSocketEventMap["message"]) => {
  const message = JSON.parse(event.data);

  // Route to appropriate handler based on message.op
  switch (message.op) {
    case "kernel-ready":
      // Initialize cells and UI state
      break;
    case "cell-op":
      // Update cell output
      break;
    case "variables":
      // Update variable values
      break;
    // ... many more operation types
  }
}
```

- Frontend Execute Request

  ↓

- WebSocket → Session.put_control_request()

  ↓

- Kernel.run() → ScopedVisitor analyzes code

  ↓

- Kernel executes cells + determines dependencies

  ↓

- Session.write_operation(CellOp, Variables, etc.)

  ↓

- WebsocketHandler.message_queue

  ↓

- WebSocket send_text() → JSON messages

  ↓

- Frontend onMessage → UI updates

Export to HTML (folder 03)

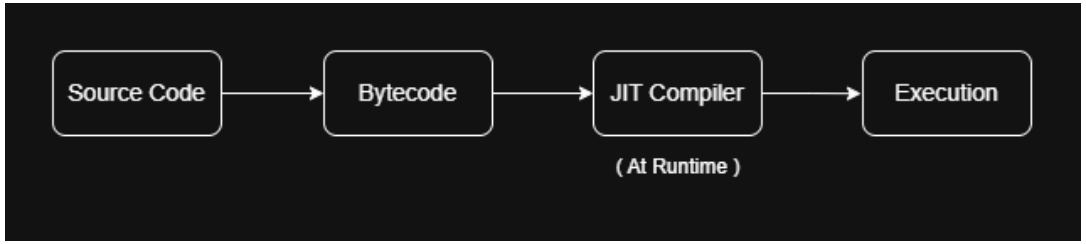
- There is no server?? How it can work?

WebAsembly

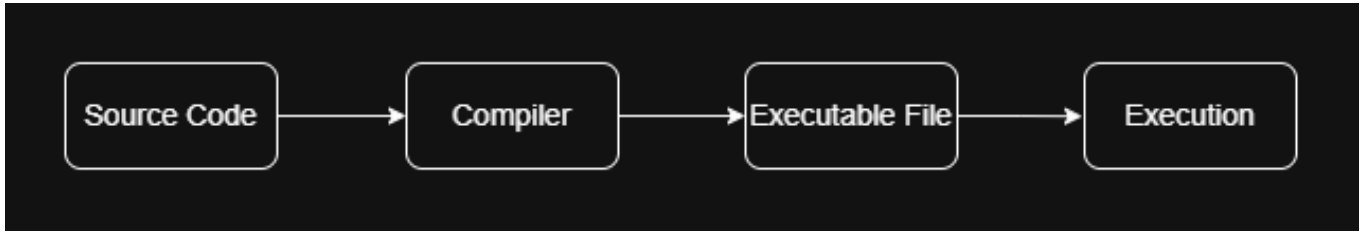
We have 3 ways how to run the code

It is not that simple even for Python … but let's ignore it for now

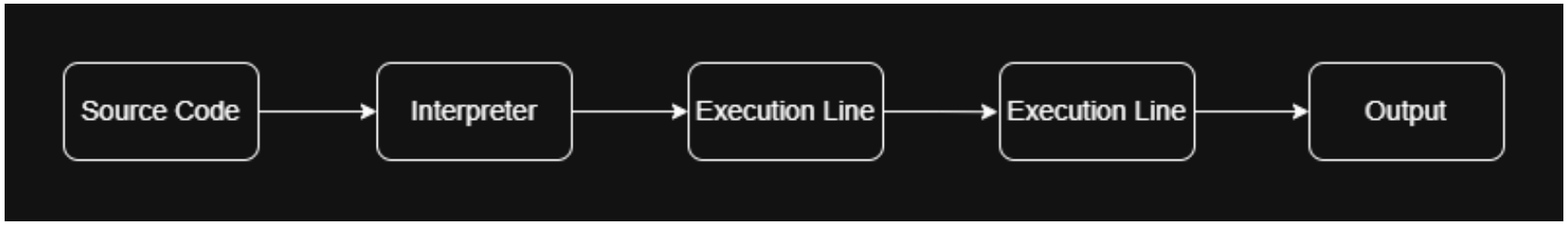
- JavaScript (V8) – Just-in-time



- WASM – Ahead-of-time compilation



- Python - CPython – Interpreter-based



C source code and corresponding WebAssembly

C source code	WebAssembly .wat text format	WebAssembly .wasm binary format

```c
int factorial(int n) {
    if (n == 0) {
        return 1;
    } else {
        return n *
factorial(n - 1);
    }
}
```

```
(func (param i64)
(result i64)
  local.get 0
  i64.eqz
  if (result i64)
      i64.const 1
  else
      local.get 0
      local.get 0
      i64.const 1
      i64.sub
      call 0
      i64.mul
  end)
```

```
00 61 73 6D 01
00 00 00
01 06 01 60 01
7E 01 7E
03 02 01 00
0A 17 01
15 00
20 00
50
04 7E
42 01
05
20 00
20 00
42 01
7D
10 00
7E
0B
0B
```

WebAssembly 101

- WebAssembly is a new type of code that can be run in modern web browsers and provides new features and major gains in performance. **It is not primarily intended to be written by hand**, rather it is designed to be an effective **compilation target** for source languages like C, C++, Rust, etc.
- WebAssembly is a different language from JavaScript, but it is not intended as a replacement.
- The virtual machine in the browser can now load and run two types of code — JavaScript AND WebAssembly.
- WebAssembly modules can be loadable just like ES modules (using <script type='module'>), meaning that JavaScript will be able to fetch, compile, and import a WebAssembly module as easily as an ES module.

https://developer.mozilla.org/en-US/docs/WebAssembly/Guides/Concepts

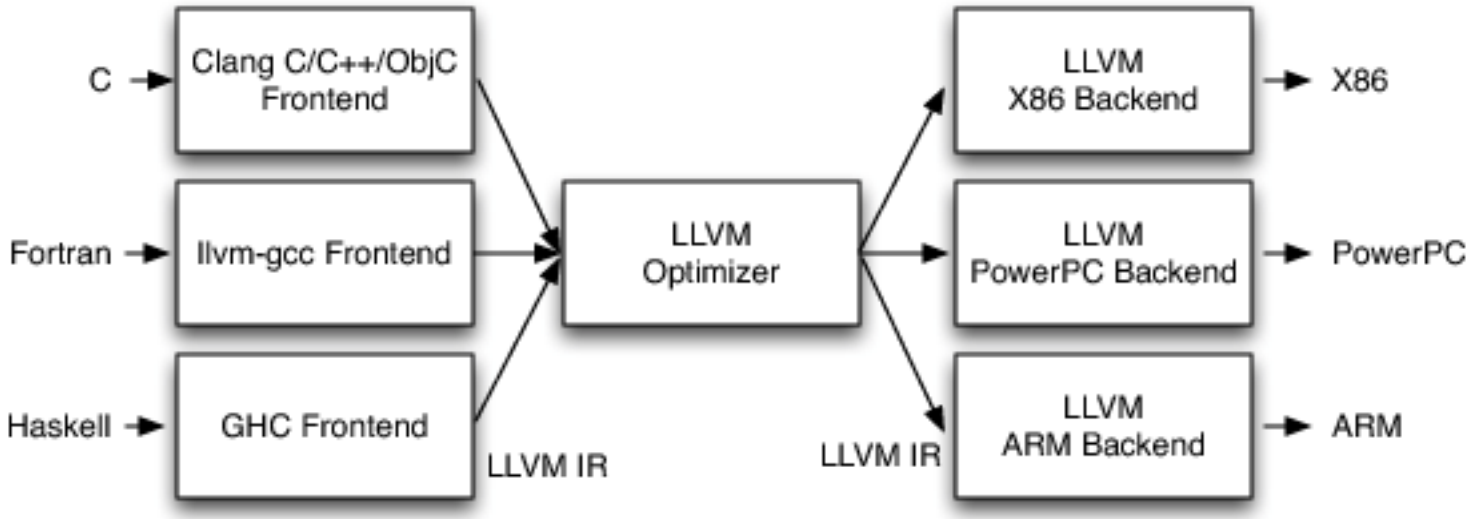
How to get WASM code?

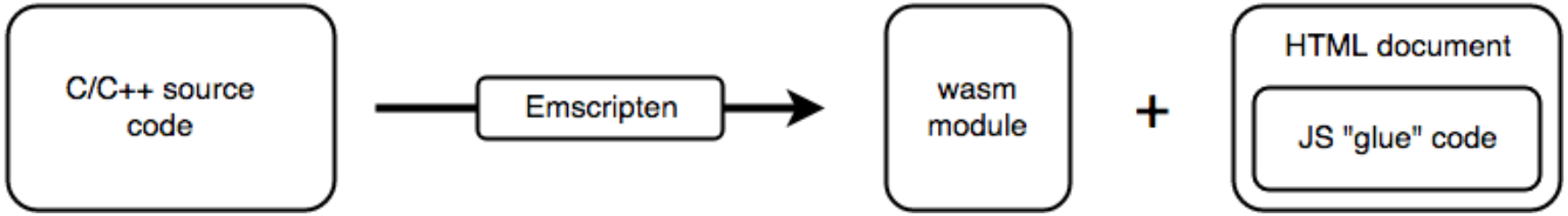
- **Porting a C/C++ application with Emscripten.**
- Writing or generating WebAssembly directly at the assembly level.
- Writing a Rust application and targeting WebAssembly as its output.
- Using AssemblyScript which looks similar to TypeScript and compiles to WebAssembly binary.

https://developer.mozilla.org/en-US/docs/WebAssembly/Guides/Concepts

Emscripten

- Emscripten is a complete compiler toolchain to WebAssembly, using **LLVM**, with a special focus on speed, size, and the Web platform.
-





Where to run this WASM code? (folder 04)

- “Server” side:
  - Wasmtime (even Python version)
  - WasmEdge
  - Lucet
- “Client + server” side:
  - Javascript (v8)

```
// Assume add.wasm file exists that contains a single function
const fs = require('node:fs');

// Use the readFileSync function to read the contents of the "a
const wasmBuffer = fs.readFileSync('/path/to/add.wasm');

// Use the WebAssembly.instantiate method to instantiate the We
WebAssembly.instantiate(wasmBuffer).then(wasmModule => {
  // Exported function lives under instance.exports object
  const { add } = wasmModule.instance.exports;
  const sum = add(5, 6);
  console.log(sum); // Outputs: 11
});
```

https://v8.dev/docs/wasm-compilation-pipeline

https://developer.mozilla.org/en-US/docs/WebAssembly/Guides/Loading_and_run

https://nodejs.org/en/learn/getting-started/nodejs-with-webassembly

https://dev.to/begoon/compile-c-to-webassembly-wasm-and-run-it-in-the-browser-h1l

WASM, so what?

WASM, so what?

WebAsembly + Python?

CPython is the key

It is getting some attention in PEP

- https://peps.python.org/pep-0776/ (PEP 776 – Emscripten Support)
- https://peps.python.org/pep-0783/ (PEP 783 – Emscripten Packaging)

- Similar way is to use Python-to-C mapping -> WASM
  - https://github.com/wasmerio/py2wasm using https://nuitka.net/
  - Nuitka translates the Python modules into a C level program that then uses libpython and static C files of its own to execute in the same way as CPython does.

Pyodide

- Pyodide is a port of CPython to WebAssembly/Emscripten.
- micropip (not confuse with microPython ☺)
- https://pyodide.org/en/stable/console.html

- https://stanford.edu/~cpiech/bio/papers/pyodideU.pdf

Other ways of using Python in browser

- https://pyscript.net/
- https://pypyjs.org/

Return from rabbit hole -> Marimo + WASM

- Folder 05 – practical examples

- https://pyvideo.org/pycon-us-2025/marimo-a-notebook-that-compiles-python-for-reproducibility-and-reusability.html