Foundations of Computer Science
Lecture 12:
Recapping and Real World Use!

Anil Madhavapeddy

1st Nov 2023

Goals of Programming

- to **describe a computation** so that it can be done *mechanically*:
  - *expressions* compute *values*
  - *commands* cause *effects*
- to do so **efficiently and correctly**, giving right answers *quickly*
- to allow **easy modification** as our needs change
  - through an orderly *structure* based on *abstraction* principles
  - programmer should be able to predict effects of changes

Why Program in OCaml?

- It is **interactive**.
- It has a flexible notion of **data type**.
- It hides the underlying hardware: **no crashes**.
- Programs can easily be **understood mathematically**.
- It **distinguishes naming** from updating memory.
- It **manages storage** in memory for us.

Language

- Static type checking
- Parametric Polymorphism
- Type Inference
- Algebraic Data Types
- Pattern Matching
- First Class Functions

$\Big\}$ **Abstraction**

Language

Static type checking

Parametric Polymorphism

Type Inference

Algebraic Data Types

Pattern Matching

First Class Functions

```
# let x = "1" + 1 ;;
Error: This expression has type string but
an expression was expected of type int
```

Language

Static type checking

Parametric Polymorphism

Type Inference

Algebraic Data Types

Pattern Matching

First Class Functions

```
# let x = "1" + 1 ;;
Error: This expression has type string but
an expression was expected of type int
```

1A Object Oriented Programming

Prof Rob Harle

Language

Static type checking

Parametric Polymorphism

Type Inference

Algebraic Data Types

Pattern Matching

First Class Functions

```
# type 'a tree =
    | Lf
    | Br of 'a * 'a tree * 'a tree
```

Language

Static type checking

Parametric Polymorphism

Type Inference

Algebraic Data Types

Pattern Matching

First Class Functions

```
# let fn l = List.map (fun (a,b) ->
      string_of_int a ^ b) l;;

val fn : (int * string) list -> string list
= <fun>
```

Language

Static type checking

Parametric Polymorphism

Type Inference

Algebraic Data Types

Pattern Matching

First Class Functions

1B Concepts in Programming Languages

1B Further Java

II Types

Language

Static type checking

Parametric Polymorphism

Type Inference

Algebraic Data Types

Pattern Matching

First Class Functions

```
# type vehicle =
      | Car of bool
      | Motorbike of int
      | Bicycle
```

Language

Static type checking

Parametric Polymorphism

Type Inference

Algebraic Data Types

Pattern Matching

First Class Functions

```
# type vehicle =
    | Car of bool
    | Motorbike of int
    | Bicycle

# match v with
  | Car false -> "car"
  | Car true  -> "reliant robin"
  ...
```

Language

Static type checking

Parametric Polymorphism

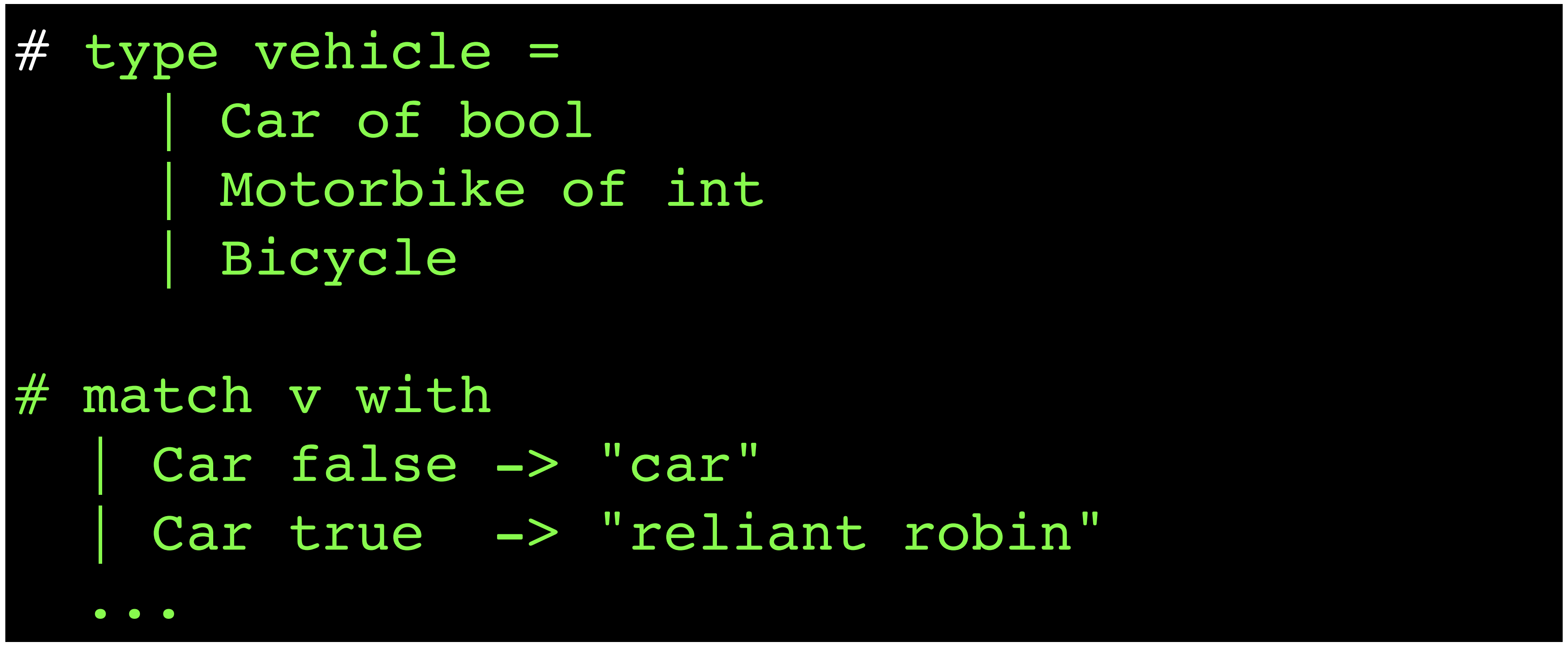
Type Inference

Algebraic Data Types

Pattern Matching

First Class Functions

1B Semantics of Programming Languages



```
# type vehicle =
    | Car of bool
    | Motorbike of int
    | Bicycle

# match v with
  | Car false -> "car"
  | Car true  -> "reliant robin"
  ...
```

Language

- Static type checking
- Parametric Polymorphism
- Type Inference
- Algebraic Data Types
- Pattern Matching
- First Class Functions

Abstraction

Runtime

- Fast Foreign Functions
- Static Linking
- Garbage Collection
- Fast Native Code
- Multiarchitecture
- Portable Bytecode

Execution

Runtime

Fast Foreign Functions

Static Linking

Garbage Collection

Fast Native Code

Multiarchitecture

Portable Bytecode

Upcoming Courses:

1A Operating Systems

1B Compiler Construction

1B Programming in C/C++

OCaml: a system

Runtime	Language
Fast Foreign Functions	Pattern Matching
Static Linking	Algebraic Data Types
Garbage Collection	Type Inference
Fast Native Code	First Class Functions
Multiarchitecture	Static type checking
Portable Bytecode	Parametric Polymorphism

OCaml (& ML): Influences

Runtime

- Fast Foreign Functions
- Static Linking
- Garbage Collection
- Fast Native Code
- Multiarchitecture
- Portable Bytecode

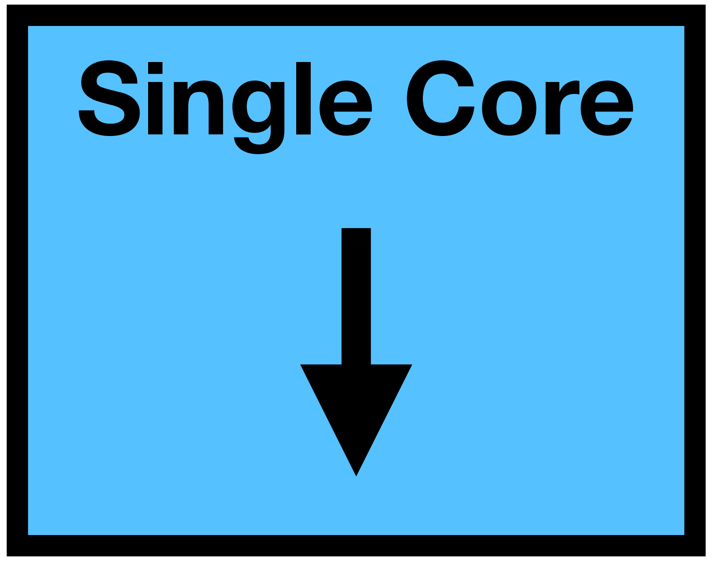
Language

- Pattern Matching
- Algebraic Data Types
- Type Inference
- First Class Functions
- Static type checking
- Parametric Polymorphism

Influenced

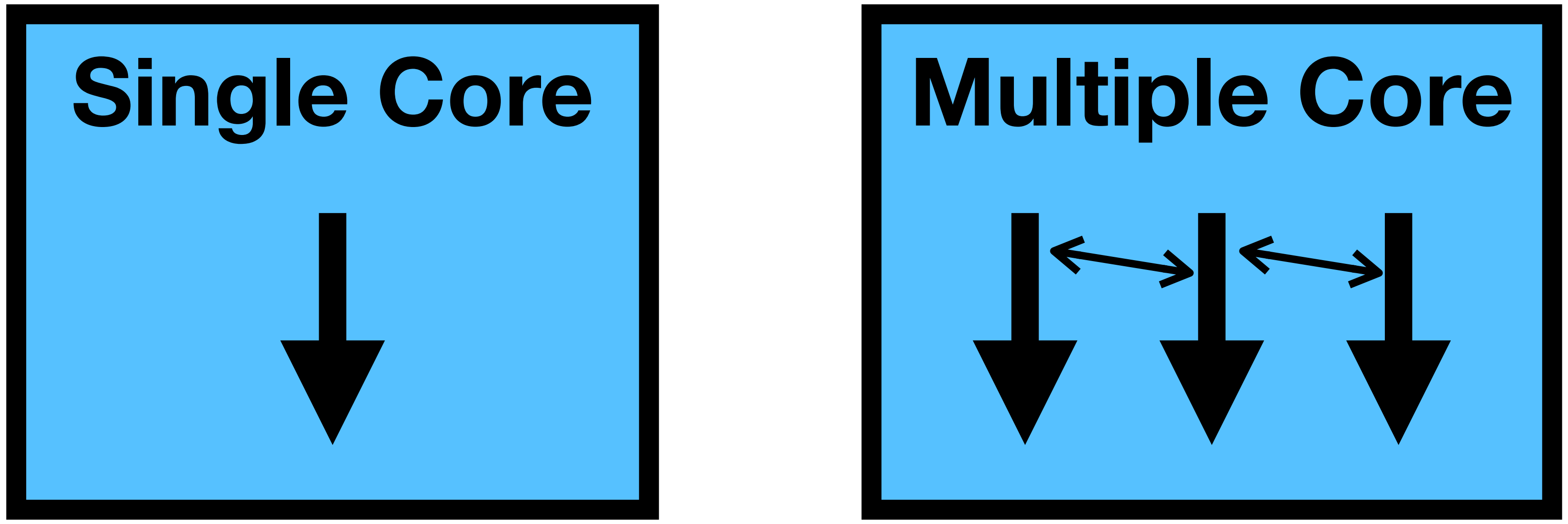
- JavaScript
- F#
- Common Lisp
- Rust
- C#
- C++
- Elm
- Java
- Scala
- Python

OCaml: scaling



Execution sequential. Why bother with immutable values?

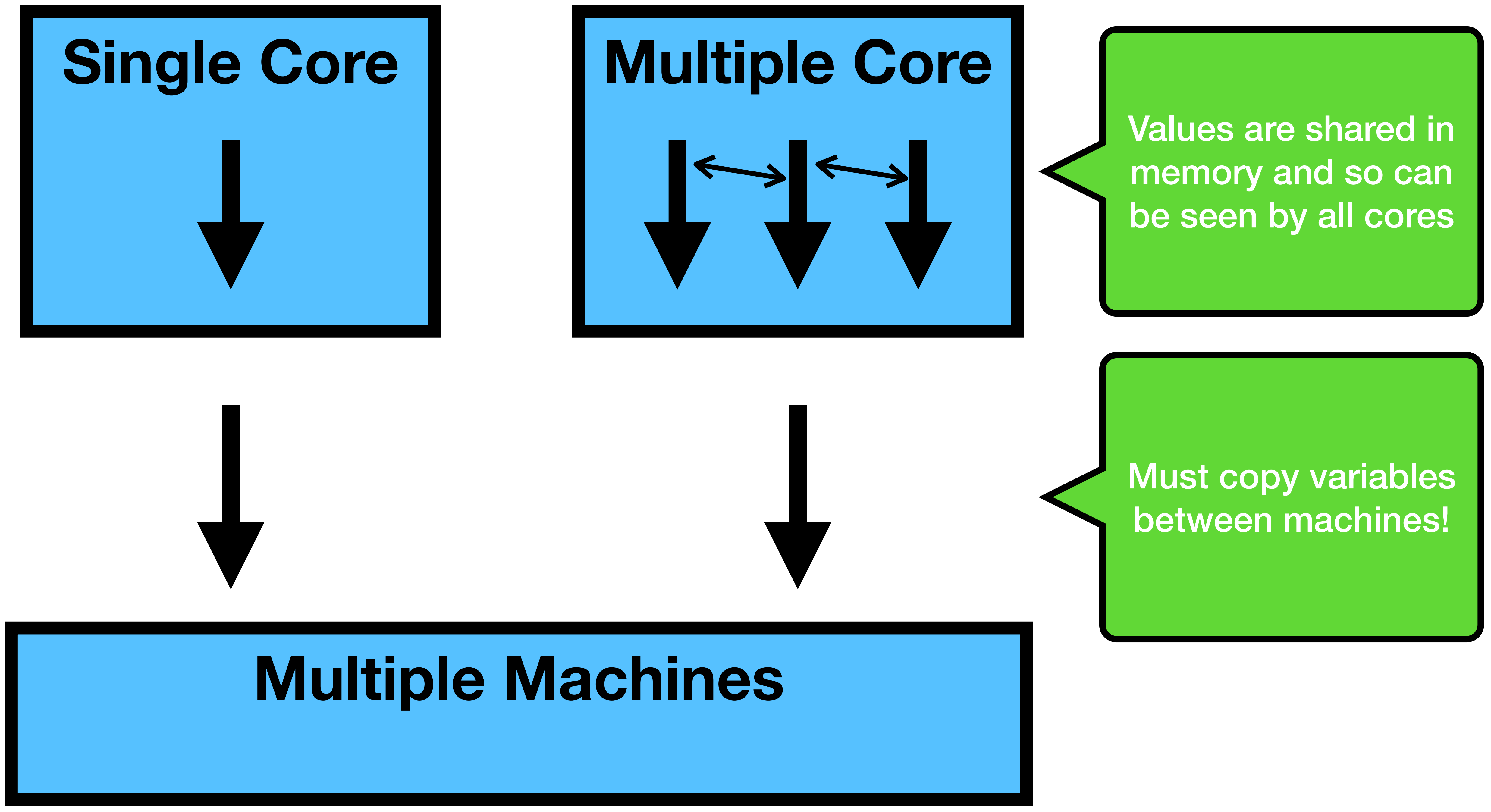
OCaml: scaling



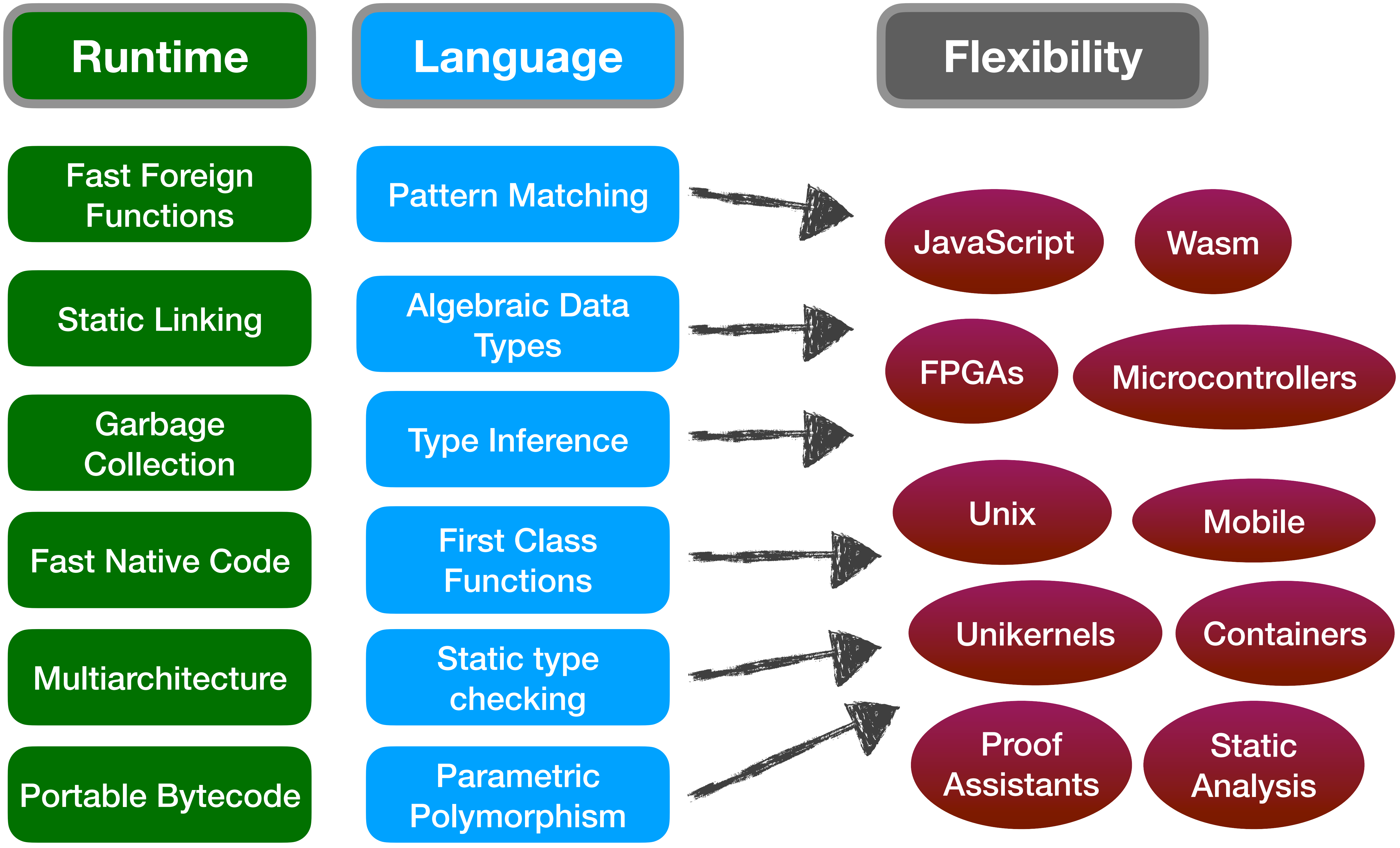
Values are shared in memory and so can be seen by all cores

OCaml: scaling

1B Concurrent & Distributed Systems


Single Core
Multiple Core
Values are shared in memory and so can be seen by all cores
Must copy variables between machines!
Multiple Machines

OCaml: Applications



OCaml: Web Programming

Runtime

- Fast Foreign Functions
- Static Linking
- Garbage Collection
- Fast Native Code
- Multiarchitecture
- Portable Bytecode

Language

- Pattern Matching
- Algebraic Data Types
- Type Inference
- First Class Functions
- Static type checking
- Parametric Polymorphism

Flexibility

JavaScript

Wasm

rescript

https://rescript-lang.org

ReScript is a robustly typed language that compiles to efficient and human-readable JavaScript. It comes with a lightning fast compiler toolchain that scales to any codebase size.

OCaml: Building Hardware

Runtime

Language

Flexibility

OCaPIC: PIC microcontrollers programmed in OCaml

Static Linking

Algebraic Data Types

FPGAs

Microcontrollers

Garbage Collect

Type Inference

Fast Native

Multiarchit

Portable By

ORCONF2015

Writing hardware in OCaml, Running OCaml in hardware

Andrew Ray

HardCaml is a structural hardware design DSL embedded in OCaml. The library can be used for front end design tasks up to the synthesis stage where a VHDL or Verilog netlist is generated. Libraries for fast simulation using LLVM, waveform viewing and co-simulation with Icarus Verilog are provided.

HardCaml-RiscV is a simple pipelined RV32I core, targetted towards a FPGA implementation and built with HardCaml.

Jane Street

Been using OCaml for twenty years or so, with ~30 million lines of code.

~2000 employees, many of whom code in OCaml, with ~600 fulltime developers.

Much of the core source code is available as open source code: realworldocaml.org

And a really fun podcast at: https://signalsandthreads.com/

Portable Bytecode

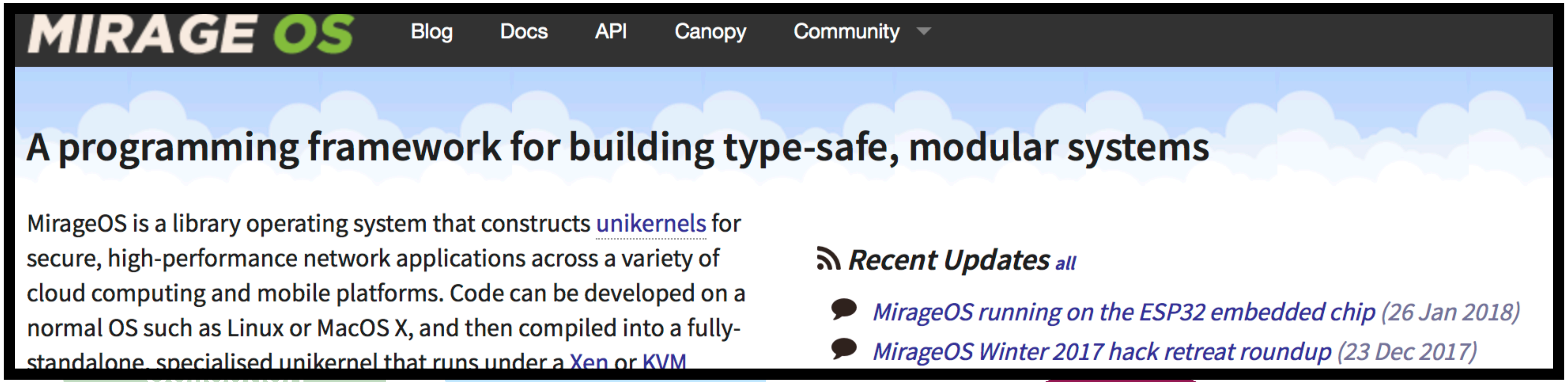
Parametric Polymorphism

OCaml: Operating Systems

Runtime

Language

Flexibility


MIRAGE OS Blog Docs API Canopy Community

A programming framework for building type-safe, modular systems

MirageOS is a library operating system that constructs unikernels for secure, high-performance network applications across a variety of cloud computing and mobile platforms. Code can be developed on a normal OS such as Linux or MacOS X, and then compiled into a fully-standalone, specialised unikernel that runs under a Xen or KVM

Recent Updates all

- MirageOS running on the ESP32 embedded chip (26 Jan 2018)
- MirageOS Winter 2017 hack retreat roundup (23 Dec 2017)

Fast Native Code

First Class Functions

Portable Bytecode

Parametric Polymorphism

Unix

Mobile

Unikernels

Containers

https://mirage.io

Docker

The most popular way to share and extend software distributions.

13m+ developers use Docker for Desktop daily.
7m+ applications developed.
13 billion monthly image downloads.

At the heart of desktop integration on Windows and Mac, there are services written in OCaml that process every byte of traffic.
https://github.com/moby/vpnkit

Find out more in Part II Cloud Computing!

OCaml: Safety Critical

Runtime

Fast Foreign Functions

Static Linkin

Garbage Collection

Fast Native Co

Multiarchitecture

Portable Bytecode

Lang

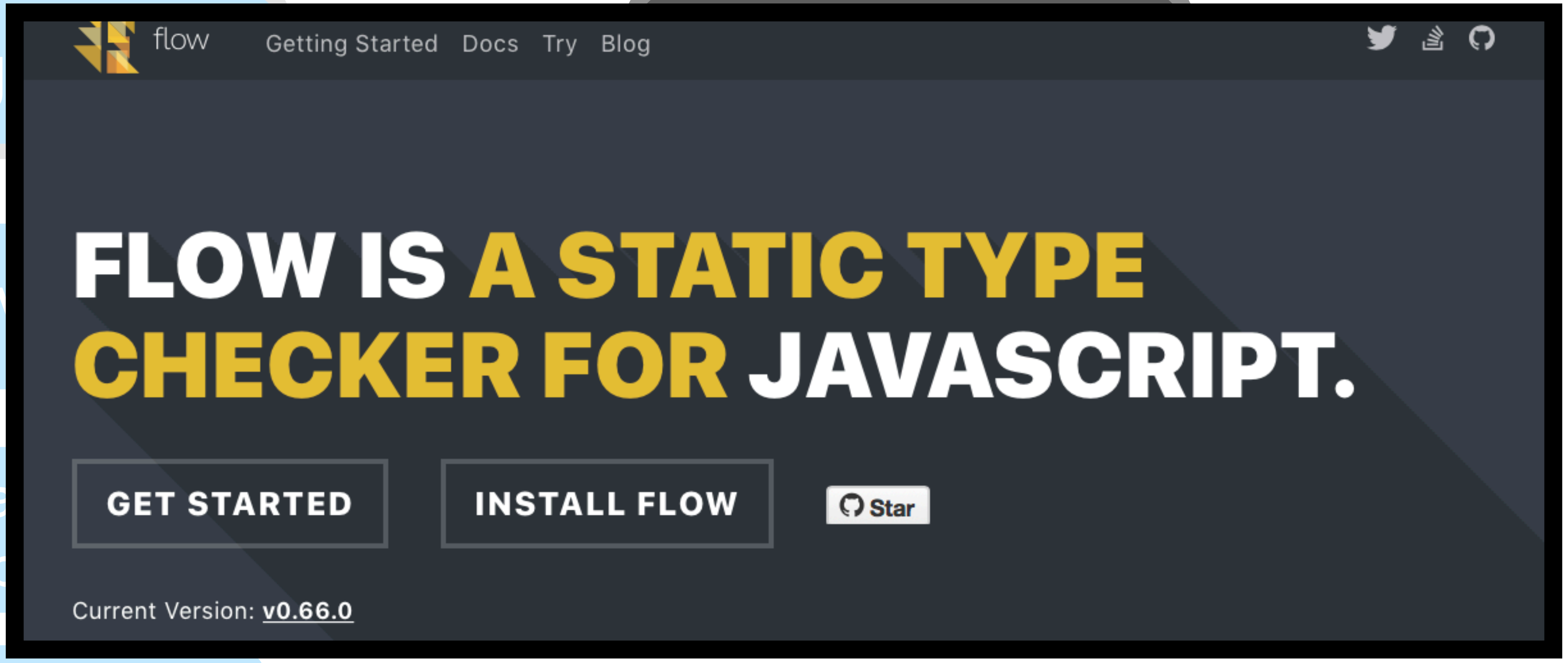
Pattern M

ebra Typ

Type Inference

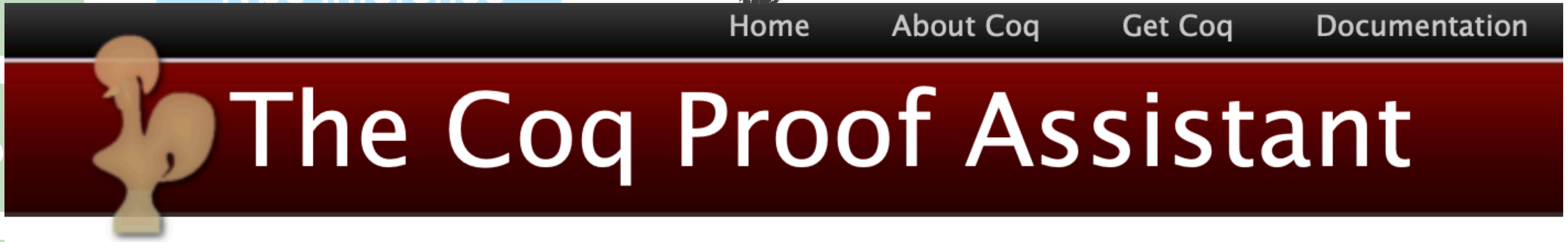
Static type checking

Parametric Polymorphism



FLOW IS A STATIC TYPE CHECKER FOR JAVASCRIPT.

Current Version: v0.66.0



The Coq Proof Assistant

https://coq.inria.fr

Proof Assistants

Static Analysis

OCaml: Predictable Robots!

Ru

Fast
Fur

Stati

Ga
Col

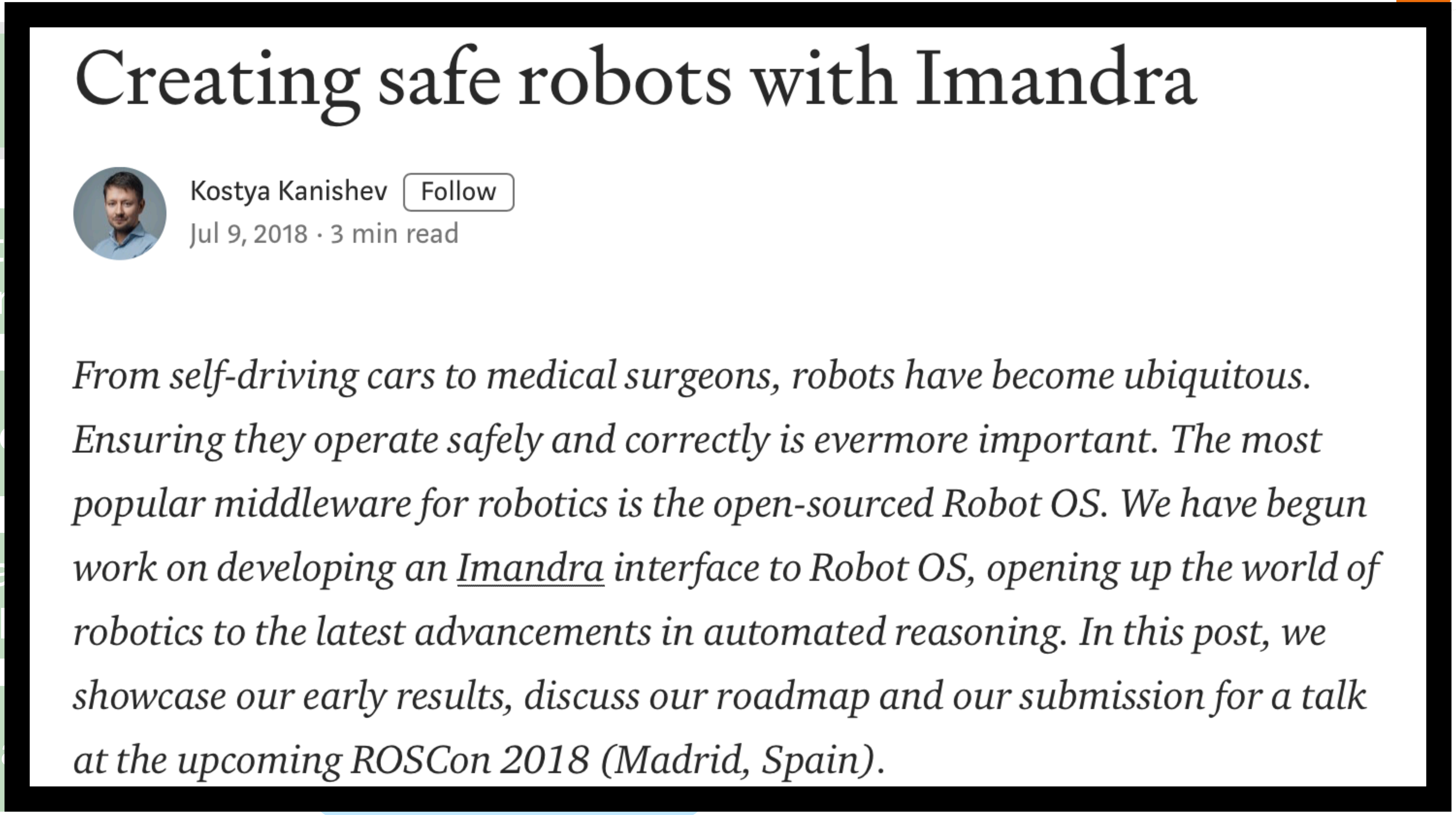
Fast N

Multiarchitecture

Portable Bytecode

Static type checking

Parametric Polymorphism



Creating safe robots with Imandra

Kostya Kanishev Follow
Jul 9, 2018 · 3 min read

From self-driving cars to medical surgeons, robots have become ubiquitous. Ensuring they operate safely and correctly is evermore important. The most popular middleware for robotics is the open-sourced Robot OS. We have begun work on developing an Imandra interface to Robot OS, opening up the world of robotics to the latest advancements in automated reasoning. In this post, we showcase our early results, discuss our roadmap and our submission for a talk at the upcoming ROSCon 2018 (Madrid, Spain).

www.imandra.ai

Proof Assistants

Static Analysis

OCaml: Data Science

Runtime

- Fast Foreign Functions
- Static Linking
- Garbage Collection
- Fast Native Code
- Multiarchitecture
- Portable Bytecode

Language

- Pattern Matching
- Algebraic Data Types
- Type Inference
- First Class Functions
- Static type checking
- Parametric Polymorphism

Flexibility

OWL

OCaml Scientific Computing

ocaml.xyz

Goals of Programming

- to **describe a computation** so that it can be done *mechanically*:
  - *expressions* compute *values*
  - *commands* cause *effects*
- to do so **efficiently and correctly**, giving right answers *quickly*
- to allow **easy modification** as our needs change
  - through an orderly *structure* based on *abstraction* principles
  - programmer should be able to predict effects of changes