Macroeconomic Modeling with Julia

Erica Moszkowski

Federal Reserve Bank of New York

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Thank yous

- Conference organizers
- DSGE team at the FRBNY
- Mary McCann
- John Stachurski, for much of the content on these slides
- You all for being here

Team

- **Chase Coleman**: Graduate student at NYU Stern, developer at QuantEcon
- **Abhi Gupta**: Senior Research Analyst at FRBNY
- **Pearl Li** : Senior Research Analyst at FRBNY
- **Spencer Lyon**: Graduate student at NYU Stern, lead developer at QuantEcon
- **Erica Moszkowski**: Senior Research Analyst at FRBNY

Goals and Assumptions

Assumptions

- Attendees are programmers but new to Julia
- Interested in macroeconomics

Goals

- Overview of Julia and comparisons to other languages
- Lower fixed costs to learning Julia
- Resources for further study

Schedule

Part 1

- Introduction and overview (Erica)

Part 2

- The Julia language (Abhi)

Part 3

- Julia for economists – libraries and features (Chase and Spencer)

Part 4

- DSGE modeling with Julia (Pearl)

Resources

http://github.com/FRBNY-DSGE/CEF_2017_Workshop

More resources listed there.

Software Options

Install

1. Julia
2. Packages (IJulia, QuantEcon.jl, DSGE.jl)
3. IDE if you like (such as Juno)

Or

1. JuliaPro

Or don't install

1. JuliaBox (juliabox.org) TODO

Scientific Computing

Using computation to solve scientific/engineering problems.

Tasks:

- Solve numerical problems
- Manipulate data
- Simulate
- Visualize results with tables and graphs
- Explore

And we often want to do these things **fast**.

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Speed is nontrivial

To get maximum speed, we need:

- Optimal use of hardware
- High level of control over operations/logic

First best: **assembly language**/machine code. This gives us instructions at the CPU level, specific to your chip architecture.

For example: $1 + 2$

1 + 2

```
    .cfi_startproc
    pushq %rbp
    .cfi_def_cfa_offset 16
    .cfi_offset 6, -16
    movq %rsp, %rbp
    .cfi_def_cfa_register 6
    movl $1, -12(%rbp)
    movl $2, -8(%rbp)
    movl -12(%rbp), %edx
    movl -8(%rbp), %eax
    addl %edx, %eax
    movl %eax, -4(%rbp)
    movl -4(%rbp), %eax
    popq %rbp
    .cfi_def_cfa 7, 8
    ret
    .cfi_endproc
```

Now imagine programming a 3-equation DSGE model like this...

You would have to optimize for specific hardware:

- Pipelining
- Cache hierarchies
- Branch prediction
- Multiprocessing
- etc, etc, etc

And change it every time there's a new processor.

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Tradeoffs

Low level languages give us:

- Speed
- Fine-grained control
- Less machine time, more programmer time

High level languages give us:

- Abstraction (from hardware, pointers, etc)
- Automation of some tasks (garbage collection)
- Natural language representations
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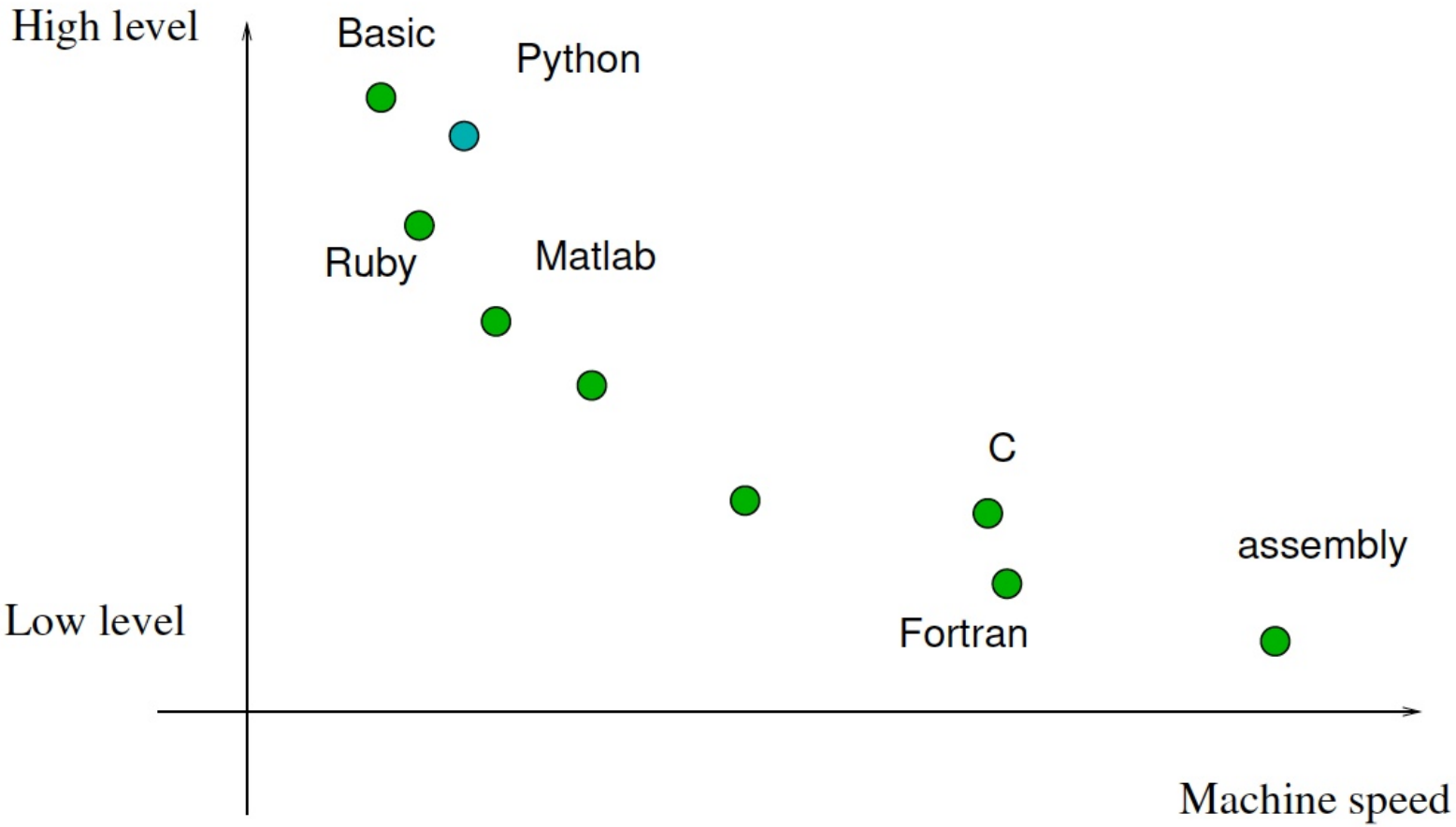
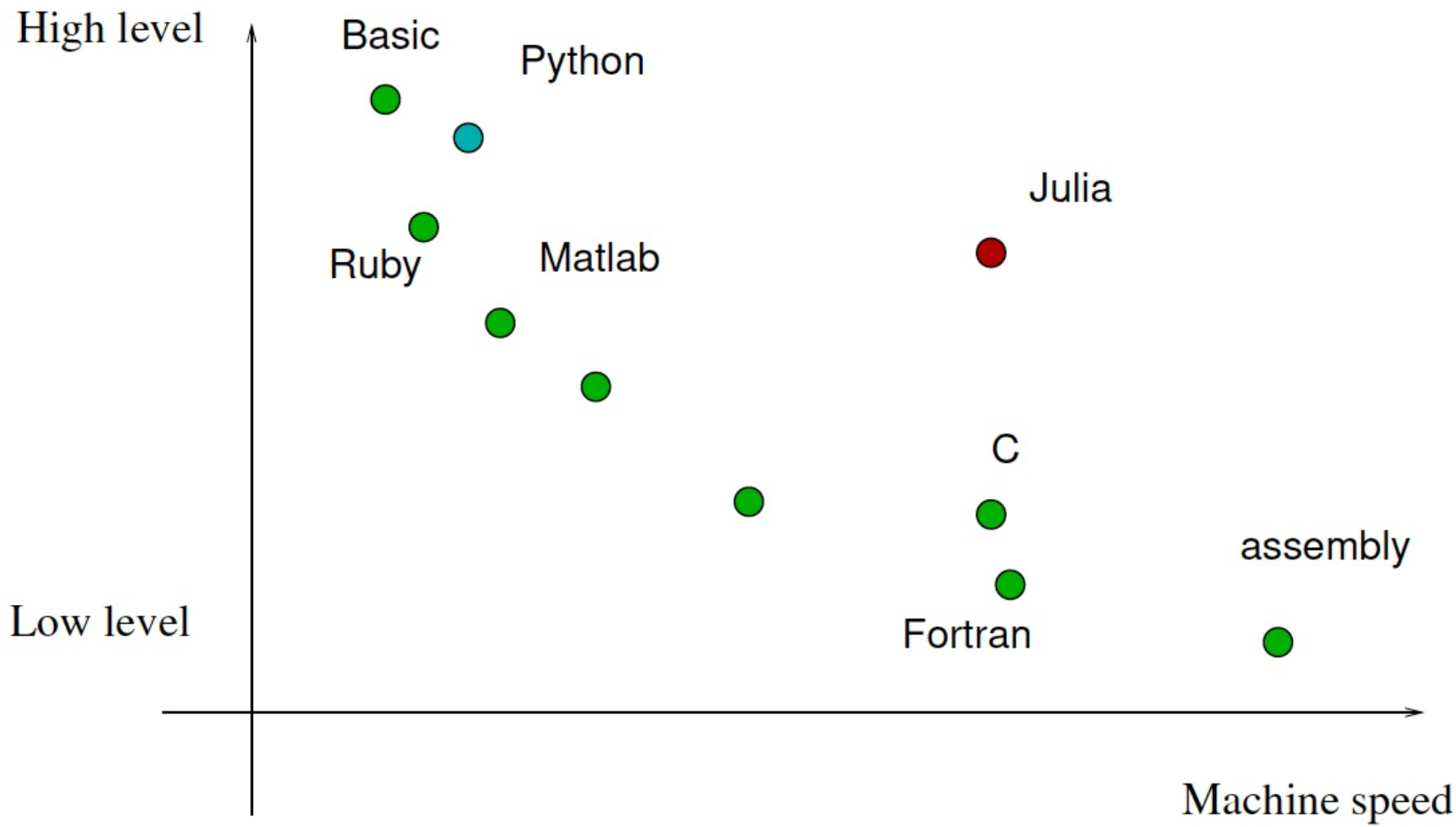


But the curve is starting to shift ...


High level
Low level
Machine speed
Basic
Python
Julia
Ruby
Matlab
C
assembly
Fortran

A Horse Race

Task:

1. Compute $X_1, X_2, \ldots, X_n$ according to $X_{t+1} = \beta + \alpha X_t + W_{t+1}$, where $W_t \sim N(0,1)$
2. Calculate and return $\frac{1}{n}\sum_{t=1}^{n} X_t$

Where $n = 10^7$

Julia Overview

High-level, open-source, scientific computing language

Strengths

- High productivity
- And high performance!

Potential Negatives

- Still under rapid development (will slow w/ v1.0)
- Lots of advanced features either out there or in development: rabbit holes abound

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Why (free and) Open Source?

- Reproducibility with minimal headache:

  Let's be clear: the work of science has nothing whatever to do with consensus. Consensus is the business of politics. Science, on the contrary, requires only one investigator who happens to be right, which means that he or she has results that are veriable by reference to the real world. In science consensus is irrelevant. What is relevant is reproducible results.

  - Michael Crichton

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Interacting with Julia

Options:

- REPL + text editor (Atom, Sublime, Emacs, etc)
  - Minimal difference from language to language
  - Customize your text editor as much as you want
- IDEs like Juno
  - Mouse support: buttons, etc
  - Possibly most familiar for MATLAB IDE users
- Jupyter notebooks

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Jupyter Notebooks

Browser-based front-end for Python, Julia, R, and increasingly more

- Easy to run in the cloud or on servers
- Allows for rich text and graphics - nice for presenting notes alongside computation

Examples: http://notebooks.quantecon.org/

Let's try one!

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