

Programming Language Concepts

Introduction

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① About the class

② Introduction

③ Rust

Lectures every **Tuesday** and **Thursday** 2pm – 3:15pm, 106 GILH

Office hours:

Adrien Champion	Tue	3:30pm–5:30pm	TBA
	Thu	3:30pm–5pm	
Richard Blair		TBA	

Grading:

- 4 Homework Assignments (Programming Assignments) 40%
- In-class Miderm Exam 20%
- Final Project 30%
- Micro assignments 10%

- you **can** discuss ideas / algorithms
- you **CANNOT** share code
- I **will not** deal with cheating, the university will

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- you **CANNOT** share code
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- assignments **in Rust**
- a **final project** you will choose, most options use Rust

Piazza for asking questions about, and discussing the class:

<https://piazza.com/class/ijfcsj0kxbf10l>

Bitbucket for lectures PDFs, syllabus, projects and assignments

<https://bitbucket.org/AdrienChampion/plc>

Software:

- (private) version control (`bitbucket` or `github`)
- `Rust` compiler (`rustc`) and project manager (`cargo`)
- unix-based system recommended (`VM` on Windows)

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Resources for Rust:

official	https://www.rust-lang.org/
online compiler	https://play.rust-lang.org/
tutorial	https://doc.rust-lang.org/stable/book/ http://rustbyexample.com/
API	https://doc.rust-lang.org/stable/std/
libraries	https://crates.io/

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From sources to runtime

- compile
- interpret

From sources to runtime

Type system

- none
- weak
- strong
- super-strong

From sources to runtime

Type system

Memory management

- manual
- heap / stack
- garbage collection

From sources to runtime

Type system

Memory management

Abstraction mechanisms

- structures
- objects
- modules
- algebraic data types
- type classes (traits)

From sources to runtime

Type system

Memory management

Abstraction mechanisms

Misc.

- compiler plugins
- macros
- indentation-has-semantics
- expressions over statements

From sources to runtime

Type system

Memory management

Abstraction mechanisms

Misc.

What is the point of studying PLC anyway?

- obviously useful for language designers
- what about developers?

Many of the low level details are “invisible” to devs, why care?

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Programming languages are tools: different tasks call for different tools

Studying **PLCs** lets us

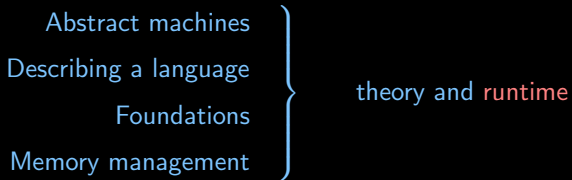
- identify quickly the **best language** for a given task,
- get a **good idea** of an unknown language quickly by looking at a few keywords
- write **better** code
thanks to a better understanding of the *abstractions* we write it with

Abstract machines


Describing a language

Foundations

Memory management



Abstract machines
Describing a language
Foundations
Memory management



theory and runtime

Names and environment

Control structures

Control abstraction

Structuring data

Data abstraction

Abstract machines
Describing a language
Foundations
Memory management

theory and runtime

Names and environment
Control structures
Control abstraction
Structuring data
Data abstraction

from source to target
abstractions, control flow

Which languages have you used or just know about?

What about them?

- in which context are they typically used? (web, software, ...)
- compiled or interpreted?
- memory management?
- type system?
- abstraction mechanisms?

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Why?

Rust

[http://www.cnet.com/news/
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- performance

compiles to LLVM,
(virtually) *no garbage collection*
zero-cost abstractions

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 - compiles to LLVM,
 - (virtually) *no garbage collection*
 - zero-cost* abstractions
- memory / thread safety
 - regional memory management*
 - strong typing, ownership, lifetimes

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- | | |
|--------------------------|--|
| • performance | compiles to LLVM,
(virtually) <i>no garbage collection</i>
zero-cost abstractions |
| • memory / thread safety | <i>regional memory management</i>
strong typing, ownership, lifetimes |
| • powerful abstractions | first-class functions, type classes |
| • defensive approach | <code>Result</code> / <code>Option</code> instead of
exceptions and <code>null</code> |

Mainstream languages **lag** behind research in language theory

Most of them

- still don't provide satisfactory solutions for **concurrency**
- are **unsafe** (memory-wise, thread-wise, ...), thus **not secure**
- are rather **slow** (may or may not be a problem):
virtual machine, garbage collection, ...
- force more **repetition** than they need to:
lack of powerful abstractions

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Software in general is more **unsafe, slow, hard to write, read, maintain** and **extend** than it could be.

- safety and performance first
- built-in support for concurrency
- hi-level abstractions
- avoid error-prone paradigms
- encourage genericity and extensibility (and documentation)
⇒ reusability and maintainability

Life cycle of memory is always the same:

- **allocate** memory you need
- **use** it (read / write)
- **free** the memory when it is not used anymore

Generally speaking,

- **allocation** is manual, happens when declaring a variable
- **using memory** is manual: actual code

Freeing memory is a challenge, in mainstream languages it can be

- *manual*: `malloc` / `free`
 - > C (1970), C++
very old-skool
- *automatic* at runtime: garbage collection
 - > Java (1995), C#, JavaScript, Python, F#, OCaml, ...

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 - > Java (1995), C#, JavaScript, Python, F#, OCaml, ...
 - actually invented in 1959 for the Lisp language
 - pretty old-skool too

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- **easy** to use, because transparent to the developer
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In general developers ♥ garbage collection:

mindless, and fast hardware hides the overhead anyway. . .

GC shows its limits when doing **expensive computations**,
potentially with a lot of allocation

For instance

- **HPC** (High Performance Calculus, applied maths),
- solving problems with **exponential complexity**,
- **web browsers** (surprisingly expensive)

Reason: GC **happens at runtime** and is **expensive**

NB: GC is not bad, but it has a cost you should be aware of

Catch as many problems as possible **statically** (compile-time)

How much can we achieve with **type-checking**?

What is type-checking anyway?

What is a **type**?

A **type** usually tells

- the size of its values (*e.g.* 64 bits)
- what it represents: an integer, a pair, a struct. . .

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With this information we can do **type-checking**:

- check that values **match** the type expected
- **failing** to compile if that's not the case, and
- **proving** “integrity” if the code type-checks

Rust tries to do more: a type is

- the usual *structural* information
- whether the “value” is *mutable*
- responsibility for *freeing* memory: *ownership*
- *lifetimes* of *references*

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- structurally *sound*
- *memory-safe* (memory leaks, dangling pointers, aliasing, ...)
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When to *deallocate* memory is a by-product of the type-checking

⇒ no overhead at runtime