PoPL

Partha Pratim Das

Why PoPL?

Prerequisites

Syllabus

Module 01
Module 02
Module 03
Module 04
Module 05
Module 06
Module 07
Module 08
Module 09
Module 10
Module 11
Module 12
Module 13

Course Information

Books
About the Course
Moodle
TA & Teacher

CS40032: Principles of Programming Languages
Module 01: Course Information

Partha Pratim Das

Department of Computer Science and Engineering
Indian Institute of Technology, Kharagpur

ppd@cse.iitkgp.ac.in

Jan 06, 2020

Expectations

PoPL
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Why PoPL?
Prerequisites
Syllabus
Module 01
Module 02
Module 03
Module 04
Module 05
Module 06
Module 07
Module 08
Module 09
Module 10
Module 11
Module 12
Module 13
Course Information
Books
About the Course
Moodle
TA & Teacher

What do you expect from this course?

Why study *Principles of Programming Languages*?

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Why PoPL?

Prerequisites

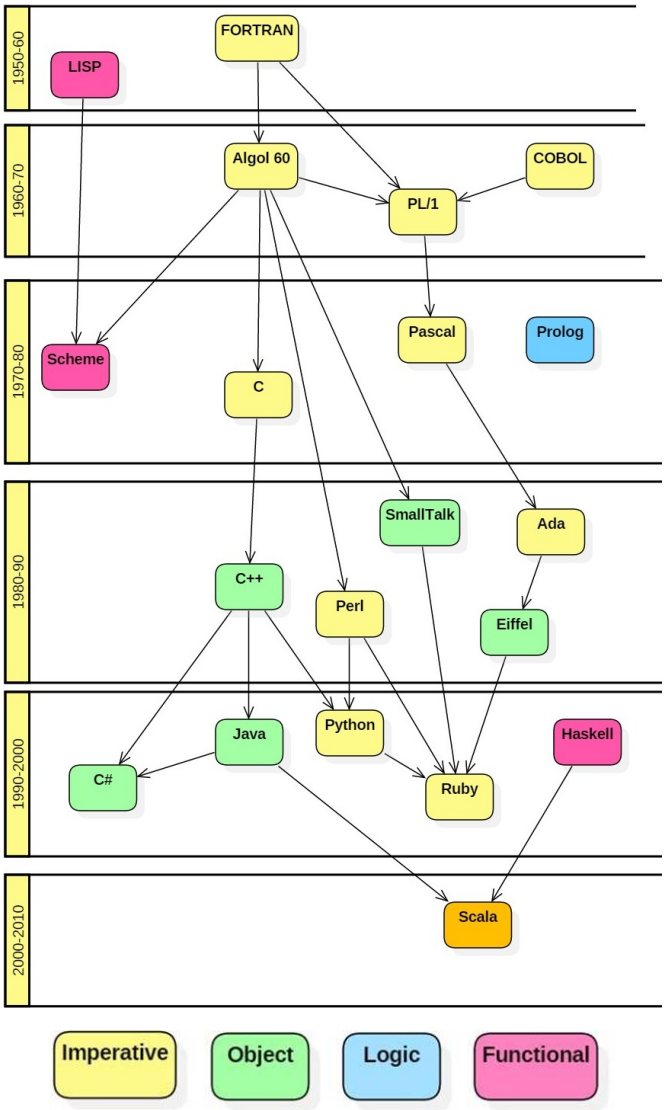
Syllabus

Module 01
Module 02
Module 03
Module 04
Module 05
Module 06
Module 07
Module 08
Module 09
Module 10
Module 11
Module 12
Module 13

Course Information

Books
About the Course
Moodle
TA & Teacher

History of Programming Languages



Paradigms: *Imperative*: Algorithms + Data, *Object*: Data, *Logic*: Facts + Rules + Queries, and *Functional*: Functions

- **FORTRAN**: IBM
- **LISP**: John McCarthy
- **Algol 60**: John Backus & Peter Naur
- **COBOL**: Grace Murray Hopper
- **PASCAL**: Niklaus Emil Wirth
- **Prolog**: Alain Colmerauer & Philippe Roussel
- **Scheme**: Guy L. Steele & Gerald Jay Sussman
- **C**: Brian W. Kernighan & Dennis M. Ritchie
- **SmallTalk**: Alan Kay, Dan Ingalls, & Adele Goldberg
- **Ada**: Jean Ichbiah & Tucker Taft
- **C++**: Bjarne Stroustrup
- **Objective-C**: Brad Cox
- **Perl**: Larry Wall
- **Java**: James Gosling
- **Python**: Guido van Rossum
- **Haskell**: Paul Hudak
- **C#**: Microsoft Corporation
- **Ruby**: Yukihiro Matsumoto
- **Scala**: Martin Odersky

Source:http://www.cs.sjsu.edu/ pearce/modules/lectures/languages2/concepts/evolution.htm

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PoPL

Partha Pratim Das

Why PoPL?

Prerequisites

Syllabus

Module 01
Module 02
Module 03
Module 04
Module 05
Module 06
Module 07
Module 08
Module 09
Module 10
Module 11
Module 12
Module 13

Course Information

Books
About the Course
Moodle
TA & Teacher

TIOBE Index of Programming Languages

Dec 2019	Dec 2018	Change	Programming Language	Ratings	Change
1	1		Java	17.253%	+1.32%
2	2		C	16.086%	+1.80%
3	3		Python	10.308%	+1.93%
4	4		C++	6.196%	-1.37%
5	6	^	C#	4.801%	+1.35%
6	5	v	Visual Basic .NET	4.743%	-2.38%
7	7		JavaScript	2.090%	-0.97%
8	8		PHP	2.048%	-0.39%
9	9		SQL	1.843%	-0.34%
10	14	^^	Swift	1.490%	+0.27%
11	17	^^	Ruby	1.314%	+0.21%
12	11	v	Delphi/Object Pascal	1.280%	-0.12%
13	10	v	Objective-C	1.204%	-0.27%
14	12	v	Assembly language	1.067%	-0.30%
15	15		Go	0.995%	-0.19%
16	16		R	0.995%	-0.12%
17	13	vv	MATLAB	0.986%	-0.30%
18	25	^^	D	0.930%	+0.42%
19	19		Visual Basic	0.929%	-0.05%
20	18	v	Perl	0.899%	-0.11%

Why study *Principles of Programming Languages*?

PoPL

Partha Pratim Das

Why PoPL?

Prerequisites

Syllabus

Module 01
Module 02
Module 03
Module 04
Module 05
Module 06
Module 07
Module 08
Module 09
Module 10
Module 11
Module 12
Module 13

Course Information

Books
About the Course
Moodle
TA & Teacher

1. **Learning Widely-Applicable Design and Implementation Techniques**
   - Domain Abstractions ⇒ Programming Language Models / Features
   - Model of Programming Language ⇒ Design and Implementation of Abstraction

Why Undergraduates Should Learn the Principles of Programming Languages? by ACM SIGPLAN (2011)

Why study *Principles of Programming Languages*?

PoPL

Partha Pratim Das

Why PoPL?

Prerequisites

Syllabus

Module 01
Module 02
Module 03
Module 04
Module 05
Module 06
Module 07
Module 08
Module 09
Module 10
Module 11
Module 12
Module 13

Course Information

Books
About the Course
Moodle
TA & Teacher

1. **Learning Widely-Applicable Design and Implementation Techniques**
   - Domain Abstractions ⇒ Programming Language Models / Features
   - Model of Programming Language ⇒ Design and Implementation of Abstraction
2. **Creating New Domain Specific Languages or Virtual Machines**
   - Mathematica and MATLAB – manipulating mathematical formulas
   - Verilog and VHDL – describing computer hardware circuit designs
   - Cg (C for Graphics) – rendering algorithms that run directly on graphics hardware
   - LaTeX – typesetting, Flex and Bison – translators, e – h/w-s/w co-design etc.

Why Undergraduates Should Learn the Principles of Programming Languages? by ACM SIGPLAN (2011)

Why study *Principles of Programming Languages*?

PoPL
Partha Pratim Das
Why PoPL?
Prerequisites
Syllabus
Module 01
Module 02
Module 03
Module 04
Module 05
Module 06
Module 07
Module 08
Module 09
Module 10
Module 11
Module 12
Module 13
Course Information
Books
About the Course
Moodle
TA & Teacher

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3. **Learning New Computational Models and Speeding Language Learning**
   - Knowledge of OOP (Java) expedites learning of C++ / C# / Python
   - Knowledge of Managed Resources (Java) expedites learning of C# / Python
   - Knowledge of Functional Programming (LISP) expedites learning MapReduce mechanism

Why Undergraduates Should Learn the Principles of Programming Languages? by ACM SIGPLAN (2011)

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PoPL

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Why PoPL?

Prerequisites

Syllabus

Module 01
Module 02
Module 03
Module 04
Module 05
Module 06
Module 07
Module 08
Module 09
Module 10
Module 11
Module 12
Module 13

Course Information

Books
About the Course
Moodle
TA & Teacher

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   - Knowledge of OOP (Java) expedites learning of C++ / C# / Python
   - Knowledge of Managed Resources (Java) expedites learning of C# / Python
   - Knowledge of Functional Programming (LISP) expedites learning MapReduce mechanism
4. **Choosing the Right Language**
   - Most systems need several languages for different parts of the system
     - HTML for front-end rendering and Javascript for active front-end logic
     - Java for servlet (business layer) and JSP for server-end embedding
     - SQL for data manipulation
   - Nature of Application decides the suitable language
     - Systems Programming ⇒ C++ (very high performance with complex behavior)
     - Embedded Programming ⇒ C (very high performance with frugal dev tools)
     - Application Programming ⇒ Java (medium performance with quick & robust app)
     - Web Programming ⇒ Python (low performance with portability)

Why Undergraduates Should Learn the Principles of Programming Languages? by ACM SIGPLAN (2011)

Understanding Computation

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Prerequisites

Syllabus

Module 01
Module 02
Module 03
Module 04
Module 05
Module 06
Module 07
Module 08
Module 09
Module 10
Module 11
Module 12
Module 13

Course Information

Books
About the Course
Moodle
TA & Teacher

1. **Languages**:
   – Fortran, LISP, Algol, Cobol, APL, Simula, SNOBOL, BASIC, PL/1, B, Pascal, Forth, C, Smalltalk, Prolog, ML, Scheme, C++, Ada, Eiffel, Objective-C, Erlang, Perl, Tcl, Haskell, Python, Visual Basic, Ruby, R, Java, Javascript, PHP, D, C#, AspectJ, Visual Basic.NET, AspectC++, Scala, F#, Go
   – SQL
   – MATLAB
   – VHDL, Verilog, SystemC, e
   - Unheard of, Aware, Can read programs, Can write programs, Have developed meaningful applications
2. **Paradigms**:
   – Imperative / Procedural, Object-Oriented, Functional, Logic, Generic / Meta-Programming, Declarative, Concurrent / Parallel
   - Unknown, Heard of, Vaguely understand, Wholly understand, Is master of
3. **Computation Model**:
   – Turing Machine, Lambda Calculus, Predicate Calculus, Relational Calculus, Communicating Sequential Processes (CSP)
   - Unknown, Heard of, Vaguely understand, Wholly understand, Is master of
4. **Application Domains**:
   – System Applications, Business Applications, Web Applications, Embedded Applications, Engineering Applications, Graphics Applications
   - Unfamiliar, Remotely familiar, Deeply familiar, Have developed meaningful applications
5. **Language – Library Trade-off**: (C++, pthread) & Java; (C++, list) & Python; (C, setjmp) & C++; (C++, SystemC) & e; (C, string) & Python;
6. ...

Prerequisites

PoPL

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Why PoPL?

Prerequisites

Syllabus

Module 01
Module 02
Module 03
Module 04
Module 05
Module 06
Module 07
Module 08
Module 09
Module 10
Module 11
Module 12
Module 13

Course Information

Books
About the Course
Moodle
TA & Teacher

1. Programming
2. Data Structure
3. Algorithms
4. Software Engineering
5. Compilers
6. Formal Languages and Automate Theory
7. Theory of Computation (desirable)

Syllabus Modules

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Prerequisites

Syllabus

Module 01

Module 02

Module 03

Module 04

Module 05

Module 06

Module 07

Module 08

Module 09

Module 10

Module 11

Module 12

Module 13

Course Information

Books

About the Course

Moodle

TA & Teacher

1. Module 01: Course Information
2. Module 02: λ Calculus – Syntax
3. Module 03: λ Calculus – Languages
4. Module 04: λ Calculus – Semantics
5. Module 05: PoPL Overview
6. Module 06: Syntax & Analysis
7. Module 07: Names
8. Module 08: Types & Type Systems
9. Module 09: Semantics & Interpretation
10. Module 10: Typed Lambda Calculus
11. Module 11: Type Systems
12. Module 12: Denotational Semantics
13. Module 13: Imperative Languages

Module 02: λ Calculus – Syntax

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Why PoPL?

Prerequisites

Syllabus

Module 01

Module 02

Module 03

Module 04

Module 05

Module 06

Module 07

Module 08

Module 09

Module 10

Module 11

Module 12

Module 13

Course Information

Books

About the Course

Moodle

TA & Teacher

1. Relations
2. Functions
    1. Compositions
    2. Currying
3. λ Calculus
    1. Concept of λ
4. λ Syntax
    1. λ Expressions
        1. Notation
    2. Example
        1. Simple
        2. Composition
        3. Boolean
        4. Numerals
        5. Recursion

Module 03: λ Calculus – Languages

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Why PoPL?

Prerequisites

Syllabus

Module 01
Module 02
Module 03
Module 04
Module 05
Module 06
Module 07
Module 08
Module 09
Module 10
Module 11
Module 12
Module 13

Course Information

Books
About the Course
Moodle
TA & Teacher

1. Overview of Functional Programming
2. Haskell
3. Scheme
4. Lisp

Module 04: λ Calculus – Semantics

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Why PoPL?

Prerequisites

Syllabus

Module 01
Module 02
Module 03
Module 04
Module 05
Module 06
Module 07
Module 08
Module 09
Module 10
Module 11
Module 12
Module 13

Course Information

Books
About the Course
Moodle
TA & Teacher

1. Free and Bound Variables
2. Substitution
3. Reduction
   1. α-Reduction
   2. β-Reduction
   3. η-Reduction
   4. δ-Reduction
4. Order of Evaluation

Module 05: PoPl Overview

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Why PoPL?

Prerequisites

Syllabus

Module 01
Module 02
Module 03
Module 04
Module 05
Module 06
Module 07
Module 08
Module 09
Module 10
Module 11
Module 12
Module 13

Course Information

Books
About the Course
Moodle
TA & Teacher

1. Principles
   1. Syntax
   2. Name
   3. Types
   4. Semantics
2. Paradigms
   1. Imperative
   2. Object-Oriented
   3. Functional
   4. Logic
   5. Generic / Meta Programming
3. Special Topics
4. History
5. On Language Design
6. Compilers and Virtual Machines

Module 06: Syntax and Analysis

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Why PoPL?

Prerequisites

Syllabus

Module 01
Module 02
Module 03
Module 04
Module 05
Module 06
Module 07
Module 08
Module 09
Module 10
Module 11
Module 12
Module 13

Course Information

Books
About the Course
Moodle
TA & Teacher

1. Chomsky's Hierarchy (of Languages)
2. Lexical Analysis
3. Syntactic Analysis

Mostly self-study

Module 07: Names

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Why PoPL?

Prerequisites

Syllabus

Module 01
Module 02
Module 03
Module 04
Module 05
Module 06
Module 07
Module 08
Module 09
Module 10
Module 11
Module 12
Module 13

Course Information

Books
About the Course
Moodle
TA & Teacher

1. Syntactic Issues
2. Variables
3. Scope
4. Symbol Table
5. Resolving References
6. Dynamic Scoping
7. Visibility
8. Overloading
9. Lifetime

Mostly self-study

Module 08: Types and Type System

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Why PoPL?

Prerequisites

Syllabus

Module 01
Module 02
Module 03
Module 04
Module 05
Module 06
Module 07
Module 08
Module 09
Module 10
Module 11
Module 12
Module 13

Course Information

Books
About the Course
Moodle
TA & Teacher

1. Type Errors
2. Static and Dynamic Typing
3. Basic Types
4. Non-Basic Types
5. Recursive Data Types
6. Functions as Types
7. Type Equivalence
8. Subtypes
9. Polymorphism and Generics
10. Programmer-Defined Types

Mostly self-study

Module 09: Types and Type System

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Why PoPL?

Prerequisites

Syllabus

Module 01
Module 02
Module 03
Module 04
Module 05
Module 06
Module 07
Module 08
Module 09
Module 10
Module 11
Module 12
Module 13

Course Information

Books
About the Course
Moodle
TA & Teacher

1. Motivation
2. Expression Semantics
3. Program State
4. Assignment Semantics
5. Control Flow Semantics
6. Input/Output Semantics
7. Exception Handling Semantics

Mostly self-study

Module 10: Typed λ Calculus

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Why PoPL?

Prerequisites

Syllabus

Module 01
Module 02
Module 03
Module 04
Module 05
Module 06
Module 07
Module 08
Module 09
Module 10
Module 11
Module 12
Module 13

Course Information

Books
About the Course
Moodle
TA & Teacher

1. $\Lambda^{\rightarrow}$
   1. Type Expression
   2. Pre-Expression & Expression
   3. Type-checking Rules
      1. Examples
2. $\Lambda^{\rightarrow}_{rr}$
   1. Types
      1. Tuple Type
      2. Record Type
      3. Sum Type
      4. Reference Type
   2. Type Expression
   3. Pre-Expression
   4. Type-checking Rules

Module 11: Type Systems

1. Overview
2. Untyped Systems

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Why PoPL?

Prerequisites

Syllabus

Module 01
Module 02
Module 03
Module 04
Module 05
Module 06
Module 07
Module 08
Module 09
Module 10
Module 11
Module 12
Module 13

Course Information

Books
About the Course
Moodle
TA & Teacher

Module 12: Denotational Semantics

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Why PoPL?

Prerequisites

Syllabus

Module 01
Module 02
Module 03
Module 04
Module 05
Module 06
Module 07
Module 08
Module 09
Module 10
Module 11
Module 12
Module 13

Course Information

Books
About the Course
Moodle
TA & Teacher

1. Styles
2. Syntax
3. Domains
   1. Domains
      1. Product
      2. Sum
   2. Rat
4. Algebra
   1. Nat, Tr
   2. String
   3. Unit
   4. Product Dom
   5. Sum Dom
   6. Lists
   7. Function
   8. Arrays
   9. Lifted Domain
   10. Recursive Function
5. Denotational Definitions
   1. Binary
   2. Calculator

Module 13: Imperative Languages

1. Imperative Languages
   1. Lifted Domains
2. Language with Assignment
3. Programs are Functions
4. Interactive File Editor
5. Dynamically Typed Language with IO
6. Recursively Defined Functions

Course Material

PoPL
Partha Pratim Das
Why PoPL?
Prerequisites
Syllabus
Module 01
Module 02
Module 03
Module 04
Module 05
Module 06
Module 07
Module 08
Module 09
Module 10
Module 11
Module 12
Module 13
Course Information
Books
About the Course
Moodle
TA & Teacher

- Slides will be uploaded to Moodle
- Books:
  - Programming Languages: Principles and Practices by Kenneth C. Louden and Kenneth A. Lambert (Cengage Learning)
  - Programming Language: Principles and Paradigms by Allen Tucker and Robert Noonan (McGraw-Hill Education)
  - Principles of Programming Languages: Design, Evaluation, and Implementation by Bruce J. MacLennan (Oxford University Press)
  - Concepts of Programming Languages by Robert W. Sebesta (Pearson)
  - Programming Language Pragmatics by Michael L. Scott (Morgan Kaufmann)
  - Compilers: Principles, Techniques, and Tools by A. V. Aho, Monica S Lam, R. Sethi, Jeffrey D. Ullman (Pearson / Addison-Wesley)
  - Books and Websites of various languages, computation models etc.

About the Course

PoPL
Partha Pratim Das
Why PoPL?
Prerequisites
Syllabus
Module 01
Module 02
Module 03
Module 04
Module 05
Module 06
Module 07
Module 08
Module 09
Module 10
Module 11
Module 12
Module 13
Course Information
Books
About the Course
Moodle
TA & Teacher

- MON(10:00-10:55), WED(08:00-08:55), WED(09:00-09:55): NC233
- Evaluation

Mid-semester	30%
End-semester	50%
Assignments	20%

- Attendance: Compulsory
- Meeting Outside Class: By appointment through mail

The Coordinating Platforms

PoPL
Partha Pratim Das
Why PoPL?
Prerequisites
Syllabus
Module 01
Module 02
Module 03
Module 04
Module 05
Module 06
Module 07
Module 08
Module 09
Module 10
Module 11
Module 12
Module 13
Course Information
Books
About the Course
Moodle
TA & Teacher

- Moodle will be used for the course. Register on Moodle immediately to:
  - CS40032: Principles of Programming Languages
- All assignments / material will be uploaded to Moodle
- All announcements will be made on Moodle. Keep checking
- ERP will also be used at times for communication. Make sure that your registered email at ERP works

TA and Teachers

PoPL

Partha Pratim Das

Why PoPL?

Prerequisites

Syllabus

Module 01
Module 02
Module 03
Module 04
Module 05
Module 06
Module 07
Module 08
Module 09
Module 10
Module 11
Module 12
Module 13

Course Information

Books
About the Course
Moodle
TA & Teacher

Sl. No.	Name	Email	Mobile / WhatsApp
1	Srijoni Majumdar	majumdar.srijoni@gmail.com	96744 74267
2	Soumen Paul	soumenpaul165@gmail.com	83360 69623
3	Arkajyoti Pal	arkapal.pal@gmail.com	86173 30249
4	Atharva Vyas	atharvavyas139@gmail.com	99320 77341
5	Tanay Bhartia	tanaybhartia@gmail.com	98003 70999
6	Partha Pratim Das	partha.p.das@gmail.com	98300 30880