編程語言的設計原理
Design Principles of Programming Languages

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胡振江、赵海燕、熊英飞

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Self-Introduction
Zhenjiang Hu

Professor
Programming Research Laboratory
Information Systems Architecture Research Division
National Institute of Informatics (NII)

Professor
Department of Informatics
The Graduate University for Advanced Studies

I received BS and MS degrees from Department of Computer Science and Engineering of Shanghai Jiaotong University in 1988 and 1991 respectively, and Ph.D degree from Department of Information Engineering of University of Tokyo in 1996. I became a lecturer (assistant professor) in 1997 and an associate professor in 2000 in University of Tokyo. I joined National Institute of Informatics as a full professor in 2008.

Research

My main interest is in programming languages and software construction in general, and functional programming, program transformation and model driven software development in particular. I am very interested in program calculation based on programming algebras, and I am looking into how to apply this theory to automatic program optimization, systematic parallelization of sequential programs, efficient manipulation of structured documents, and bidirectional model transformation for software development.

Currently, I have a post-doc position available for those who are interested in bidirectional transformation. I welcome excellent people to join my group as intern students, PhD students, or post-doc researchers (JSPS Fellowship Program and DAAD-NII Program).

Current Projects [under list]

http://www.research.nii.ac.jp/~hu
About Me

• 1988: BS, Computer Science, Shanghai Jiaotong Univ.
• 1991: MS, Computer Science, Shanghai Jiaotong Univ.
• 1996: PhD, Information Engineering, Univ. of Tokyo
• 1996: Assistant Professor, Univ. of Tokyo
• 1997: Lecturer, Univ. of Tokyo
• 2000: Associate Professor, Univ. of Tokyo
• 2008: Full Professor, National Institute of Informatics

北京大学海外杰青(2006-2008)
北京大学长江学者教授(2013.12-)
Research Interest

• **Functional Programming**
  – **Calculating Efficient Functional Programs**
  – ACM ICFP 2011 General Co-Chair
  – ACM ICFP Steering Committee Co-Chair (2012-2013)
  – AMC Haskell Symposium Steering Committee Member (2014-)

• **Algorithmic Languages and Calculi**
  – **Parallel programming and Automatic Parallelization**
  – IFIP WG 2.1 Member (IFIP TC 2, Japan Representative)

• **Bidirectional Transformation Languages in SE**
  – **Bidirectional languages for software evolution**
  – Steering Committee Member of BX, ICMT
About Prof. Zhao

• 2003    : PhD, Univ. of Tokyo
• 2003 - : Associate Professor, Peking Univ.

• Research Interest
  – Software engineering
  – Requirements Engineering, Requirements reuse in particular
  – Model transformations
  – Programming Languages

• Contact:
  – Office: Rm. 1809, Science Blg #1
  – Email: zhhy@sei.pku.edu.cn
  – Phone: 62757670
About Prof. Xiong

• 2009: PhD, Univ. of Tokyo
• 2009-2011: Postdoc, Univ. of Waterloo
• 2012: 百人计划研究员, Peking Univ.

• Research Interest
  – Program Analysis
  – Fault Localization & Repair
  – Program Synthesis

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Course Overview
What is this course about?

• Study fundamental (formal) approaches to describing program behaviors that are both precise and abstract.

  – precise so that we can use mathematical tools to formalize and check interesting properties

  – abstract so that properties of interest can be discussed clearly, without getting bogged down in low-level details
What you can get out of this course?

• A more sophisticated perspective on programs, programming languages, and the activity of programming
  – How to view programs and whole languages as formal, mathematical objects
  – How to make and prove rigorous claims about them
  – Detailed study of a range of basic language features

• Powerful tools/techniques for language design, description, and analysis
This course is not about …

• An introduction to programming
• A course on compiler
• A course on functional programming
• A course on language paradigms/styles

All the above are certainly helpful for your deep understanding of this course.
What background is required?

• Basic knowledge on
  – Discrete mathematics: sets, functions, relations, orders
  – Algorithms: list, tree, graph, stack, queue, heap
  – Elementary logics: propositional logic, first-order logic

• Familiar with a programming language and basic knowledge of compiler construction
Textbook

- **Types and Programming Languages**
- 作者: Benjamin Pierce
- 出版社: The MIT Press
- 出版年: 2002-02-01
- 页数: 648
- 定价: USD 72.00
- 装帧: Hardcover
- ISBN: 9780262162098
Outline

• Basic operational semantics and proof techniques
• Untyped Lambda calculus
• Simple typed Lambda calculus
• Simple extensions (basic and derived types)
• References
• Exceptions
• Subtyping
• Recursive types
• Polymorphism
Grading

- Activity in class: 20%
- Homework: 40%
- Final (Report/Presentation): 40%

Design a programming language with a type system, solving practical problems, and giving a basic implementation.
- Design a programming language without deadlocks
- Design a type system that embeds complexity, ensuring that the written program’s complexity does not exceed that of the type system.
- Design a type system that ensures sensitive information will never be leaked.
- Design a type system that ensures parallel programs do not have race conditions.
- Design a type system that ensures all floating-point calculations meet a certain precision requirement.
- Design a differential programming language, ensuring that the written expressions are differentiable.
- Design a probability programming language, implementing probability models and giving derivations.
- Solve specific problems in your research area.
How to study this course?

• **Before class**: scanning through the chapters to learn and gain feeling about what will be studied

• **In class**: trying your best to understand the contents and speaking out when you have questions

• **After class**: doing exercises seriously

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<th>30 seconds to 5 minutes</th>
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<tr>
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<td>≤ 3 hours</td>
</tr>
<tr>
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<td>Challenging</td>
<td>&gt; 3 hours</td>
</tr>
</tbody>
</table>
Personnel

- **Instructors**
  - Zhenjiang Hu, Professor, NII/PKU  
    hu@nii.ac.jp
  - Haiyan Zhao, Associate Professor, PKU  
    zhhy@sei.pku.edu.cn
  - Yingfei Xiong, Assistant Professor, PKU  
    xiongyf@pku.edu.cn

- **Teaching Assistant:**
  - 刘鑫远, liuxinyuan@pku.edu.cn
Information

• Course website:

   http://sei.pku.edu.cn/~xiongyf04/DPPL/main.htm

   – Syllabus
   – News/Announcements
   – Lecture Notes (slides)
   – Other useful resources
北京大学

北京大学最好的计算机类课程有哪些？

吴争译， 但是鸽子为什么这么大呢？
王逊 戴 海成 每 18 人赞同

编程语言的设计原理 编程语言的设计原理 授课老师：胡振江. 赵海燕. 胡英飞

利益相关：胡英飞是我的本科导师

这课用的教材是TAPL，Types and Programming Languages. 书很经典，讲的也比较深，我看了一些其他用这本书的学校稍微讲的讲和讲讲 recursive typing 面后的一些拓展都不讲。三位老师本身都是在PL方面的学者，讲的也还不错，而且前期还会让同学们现场写代码，不管是否有志于进行PL研究 还是 想加深对于编程语言认识的同学都有帮助。缺点是后面内容有点赶，而且我认为这课最好还是有个formal的exam比较好。

另外熊老师的软件分析技术 软件分析技术 我看过不少课件，应该也是好课，但我自己没上过。
@熊英飞

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Chapter 1: Introduction

What is a type system?
What type systems are good for?
Type Systems and Programming Languages
Why type system?

- Art vs. Knowledge
  - Art cannot be taught, while knowledge can
  - What people have invented
  - How to interpret them abstractly
  - How to reason their properties formally

- Why formal reasoning important
  - Poorly designed languages widely used
    - Java array flaw
    - PHP, Javascript, etc.
  - Well designed language needs strictly reasoning
    - Devils in details

The three worst programming languages:
https://medium.com/smalltalk-talk/the-three-worst-programming-languages-b1ec25a232c1#jdsfib20v
What is a type system (type theory)?

- A type system is a tractable syntactic method for proving the absence of certain (bad) program behaviors by classifying phrases according to the kinds of values they compute.
  
  - Tools for program reasoning
  - Fully automatic (and efficient)
  - Classification of terms
  - Static approximation
  - Proving the absence rather than presence
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Tractable: be finished in short time, often polynomial
Syntactic: be part of the programming language
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True, false    Boolean
1, 2, 3, …    Int
‘a’, ‘b’, ‘c’, …    Char
What is a type system (type theory)?

- A type system is a tractable syntactic method for proving the absence of certain (bad) program behaviors by classifying phrases according to the kinds of values they compute.
- Tools for program reasoning
- Fully automatic (and efficient)
- Classification of terms
- Static approximation
- Proving the absence rather than presence

Given a property that correct programs should satisfy, does this program satisfy it?

- Based on Rice’s theorem, we cannot precisely answer the question on any non-trivial property
- Approximation method 1 (type checking): only determine the program definitely satisfies a property
- Approximation method 2 (testing): only determine the program definitely violates a property
- Can you give a correct program that cannot type-check?
  - Static approximation
  - Proving the absence rather than presence
What are type systems good for?

- Detecting Errors
  - Many programming errors can be detected early, fixed intermediately and easily.

- Abstraction
  - Type systems form the backbone of the module languages: an interface itself can be viewed as “the type of a module.”

- Documentation
  - The type declarations in procedure headers and module interfaces constitute a form of (checkable) documentation.

- Language Safety
  - A safe language is one that protects its own abstractions.

- Efficiency
  - Removal of dynamic checking; smart code-generation
Type Systems and Languages Design

• Language design should go hand-in-hand with type system design.

  – Languages without type systems tend to offer features that make typechecking difficult or infeasible.

  – Concrete syntax of typed languages tends to be more complicated than that of untyped languages, since type annotations must be taken into account.

In typed languages the type system itself is often taken as the foundation of the design and the organizing principle in light of which every other aspect of the design is considered.
Homework

• Read Chapters 1 and 2.

• Install OCaml and read “Basics”
  – http://caml.inria.fr/download.en.html
  – http://ocaml.org/learn/tutorials/basics.html