CS520 Theory of Programming Languages

Introduction

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How to analyze programming languages (their constructs, type systems, implementations, etc) formally?

We will study mathematical tools for doing such analysis.

Preview 1:
Abstract syntax

- What is a program? What kind of syntactic object is it?

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Preview 1: Abstract syntax

- What is a program? What kind of syntactic object is it?
- Bad answer: a sequence of characters.
- Our answer: an instance of an abstract syntax.
- Mathematically, an element of an initial algebra.

Preview 2:
Domain theory

```
>>> def F(g): return g
...
```

- Which mathematical object does the program F denote?

Preview 2: Domain theory

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...
```

- Which mathematical object does the program F denote?
- Identity function in [D→D] for some D.

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>>> def F(g): return g
...
>>> F(F)
<function F at 0x10c573410>
```

- Which mathematical object does the program F denote?
- Identity function in [D→D] for some D.
- But D should include [D→D]. Impossible if D is a set.

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>>> def F(g): return g
...
>>> F(F)
<function F at 0x10c573410>
```

- Which mathematical object does the program F denote?
- Identity function in [D→D] for some D.
- But D should include [D→D]. Impossible if D is a set.
- Possible if D is a domain & [D→D] has only continuous fns.

Preview 3: Evaluation order

```
>>> def f(x): return (x+x)
...
>>> f(f(3))
12
```

- Should we compute f(3) before applying f to f(3)?

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- Should we compute f(3) before applying f to f(3)?
- Yes. Eager evaluation. Python, OCaml, Scheme, etc.
- No. Normal-order evaluation or lazy evaluation. Haskell.

Preview 3: Evaluation order

```
>>> def f(x): return 3
...
>>> f(f(3))
12
```

- Should we compute f(3) before applying f to f(3)?
- Yes. Eager evaluation. Python, OCaml, Scheme, etc.
- No. Normal-order evaluation or lazy evaluation. Haskell.

Preview 3: Evaluation order

```
>>> def f(x): return 3
...
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12
```

- Should we compute f(3) before applying f to f(3)?
- Yes. Eager evaluation. Python, OCaml, Scheme, etc.
- No. Normal-order evaluation or lazy evaluation. Haskell.
- To be analysed via operational and denotational semantics.

Preview 4:
Type system

```
import typing
from typing import Callable

def twice(f : Callable[[int],int], x : int) -> int:
  return(f(f(x)))
```

- Types help develop correct programs.

Preview 4:
Type system

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import typing
from typing import Callable

def twice(f : Callable[[int],int], x : int) -> int:
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```

- Types help develop correct programs.
- Can we infer types automatically?
- What mathematical objects do types denote?

Preview 4:
Type system

```
import typing
from typing import Callable

def twice(f : Callable[[int],int], x : int) -> int:
  return(f(f(x)))
```

- Types help develop correct programs.
- Can we infer types automatically? Type inference algo.
- What mathematical objects do types denote? Partial equivalence relation.

- Predicate Logic (Ch1).
- The Simple Imperative Language (Ch2).
- Program Specification and Their Proofs (Ch3).
- Failure, Input-Output, and Continuation (Ch5).
- Transition Semantics (Ch6).
- An Introduction to Category Theory (Tennent Ch8).
- Recursively-Defined Domains (Tennent Ch10).
- The Lambda Calculus (Ch10).
- An Eager Functional Language (Ch11).
- Continuation in a Functional Language (Ch12).
- Iswim-like Languages (Ch13).
- A Normal-Order Language (Ch14).
- The Simple Type System (Ch15).

Imperative Languages

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Functional Languages

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Math tools

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Functional Languages

Course webpage

https://github.com/hongseok-yang/graduatePL18

- Primary source of information about the course.

Blackboard lectures

- Nearly all the lectures will use blackboard, not slides.

- My handwritten notes will be available in the course webpage.

Evaluation

- Final exam — 40%.
- Homework (4 to 6 problem sheets) — 30%.
- Two critical reviews — 30%.

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Critical reviews

- Read an assigned book chapter or research papers.
- Write a review (up to 3 pages).
- Try to go beyond simple summary.
- Your own thoughts. Connection with other PL concepts. Or further in-depth study.

Review assignment 1

- Deadline: 26 Oct (Friday). By midnight.
- Material: Chapter 7 of our textbook.
- Topic: Nondeterminism and weakest preconditions.

Review assignment 2

- Deadline: 3 Dec (Monday). By midnight.

- Material: “Monads for Functional Programming” and “Computational Lambda-Calculus and Monad”.

- Topic: Monad.

Teaching staffs

- Prof Hongseok Yang (Lecturer). hongseok00@gmail.com. Office hour: 6pm-7pm on Tue at 3403 in E3-1.
- Mr Hyoungjin Lim (TA1). lmkmkr@kaist.ac.kr
- Mr Hangyeol Yu (TA2). yhk1344@kaist.ac.kr
- TAs' office hours will be announced shortly.

Schedule change

The following four lectures are cancelled:

6 Sep (Thu), 4 Oct (Thu), 4 Dec (Tue), 6 Dec (Thu).

We will have two additional lectures:

1. 9:30 - 11:30 on 18 Oct (Thu) during the midterm period.

2. 4pm - 6pm on 30 Nov (Fri).