Advanced topics in programming languages

Michaelmas 2024

## Introduction & overview

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## About the class

### Intraseminar structure



Analysing

### Interseminar structure



## What you'll do each week



### **Presentation slot assignments**



## How to get high marks in this class

## How to get a high mark in an essay

Structure

High marks ● ○ ○ ○

Low marks

ΡL

Running

Designing

Analysing

Essay marks are awarded for *understanding*, for *insight and analysis*, and for *writing quality*.

Essays should be around 1500 words.

- 1. Contextualise *widely*
- 2. Analyse *deeply*
- 3. Appraise *thoughtfully*
- 4. Elucidate *carefully*

- 5. Describe originally
- 6. Synthesise insightfully
- 7. Expound illustratively
- 8. Write *stylishly*

Media





Low marks

PL

### Read a book



JOSEPH M. WILLIAMS JOSEPH BIZUP



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#### Read *some papers*

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			Dependent type-safe i	patax and evaluation
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## How to get a high mark in a presentation



Running

Designing

Presentation marks are awarded for *clarity*, for *effective communication*, and for *selection and organisation of topics* 

- 1. engage with the audience
- 2. *empathize* with the audience
- 3. bring people along

- 4. explain the problem
- 5. bring out the key idea
- 6. have one key example

Analysing



High marks ● ● ● ●

Low marks

ΡL

Running

Designing

Analysing

#### Read a book



DESIGN AND TYPOGRAPHIC PRINCIPLE FOR THE VISUAL NOVICE

ROBIN WILLIAMS

#### Look at some slides

## How to give a great research talk

Simon Peyton Jones Microsoft Research Cambridge

Microsoft

#### Watch a presentation



## How to get low marks in this class

## How to get a low mark in an essay



## How to get a low mark in a presentation



# point lots of text

### 3. stuff your slides



### 4. disregard structure

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# Programming languages: themes

## Views of programs



## Q: what *is* a program?

### **Undecidable questions**



Q: what undecidable question are we approximating?

## Overview



# Running programs

## Garbage collection

#### Structure

High marks

Low marks

ΡL

Running

Designing

Analysing

Question: How can we efficiently automatically reclaim storage that is no longer needed by a program?

A program is a process that mutates memory by allocating, freeing, reading and writing blocks of memory

What's undecidable? Liveness: it is not possible to determine whether each value can be used by the program in future





## **Delimited continuations**



## Designing programming languages

## **Dependent types**

Structure

High marks

Low marks

ΡL

Running

Designing

Analysing

*Question:* How can we build a powerful, usable, and efficient programming language out of type theory?

A program is a blend of logic and computation.

4" / Y /

VIdris

 $\begin{array}{l} m < n \Rightarrow n \neq 0 : m < n \rightarrow n \neq 0 \\ m < n \Rightarrow n \neq 0 \quad (s \leq s \ m \leq n) \end{array} ()$ 

What's undecidable? Type equivalence is undecidable in general

More questions: How should we handle equality? How might we write programs in a dependently-typed language? How might we compile programs effectively?

## Module systems

#### Structure

High marks

Low marks

PL

Running

Designing

Analysing

Question: How might language design support assembling systems from well-specified components?

A program is a large modular system assembled from separately-defined components.

```
module type SET =

sig

type t

type elem

val empty : t

val add : elem \rightarrow t \rightarrow t

val mem : elem \rightarrow t \rightarrow bool

end

module MakeSet (Elem: ORDERED) :

SET with type elem = Elem.t
```

More questions:

How can we support abstraction and flexible composition? What might a core language of modules look like? How might we add support for recursion, higher-order modules, and first-class modules?

What problems might arise in sophisticated module systems?

Analysing programs

### **Abstract interpretation**



## **Partial evaluation**



## **Program synthesis**

#### Structure

High marks

Low marks

ΡL

Running

Designing

Analysing

*Question:* How can we generate programs from specifications?

A program is an object in a very large search space.

What's undecidable? Whether a program meets a specification is undecidable in general.

