Finding People and Information (1)

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Finding People and Information (2)

- Main module web page:
  
  www.cs.nott.ac.uk/~nhn/G53CMP
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- Moodle: moodle.nottingham.ac.uk/course/view.php?id=23959
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- Direct questions concerning lectures and coursework to the *Moodle G53CMP Forum*.
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- Direct questions concerning lectures and coursework to the *Moodle G53CMP Forum*. Anyone can ask and answer questions, but you must not post exact solutions to the coursework.
Aims and Motivation (1)

- **Aims**: Deepened understanding of:
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- **Aims:** Deepened understanding of:
  - how compilers (and interpreters) work and are constructed
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  - how compilers (and interpreters) work and are constructed
  - programming language design and semantics
- The former is a great, “hands on”, “learning-by-doing” way to learn the latter.
Aims and Motivation (2)

- *Why?*
Why? Because programming languages and tools are at the very core of Computer Science and Software Engineering.
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- There are 100s of programming languages . . .
**Aims and Motivation (2)**

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  - using the languages you know much more effectively.
Aims and Motivation (3)

- *Moreover:* Compilers: “a microcosm of computer science” [CT04]
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- Formal Languages and Automata Theory
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- Computer architecture
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- Formal reasoning about programs
- Software engineering aspects
Aims and Motivation (4)

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  - **G51CSA**: how computers work
  - **G54FOP/FPP**: programming language theory
Aims and Motivation (5)

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- **Jobs?** There are plenty of companies out there with in-house languages or that critically rely on compiler/interpreter expertise for other reasons. Some possibly surprising examples:
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- Facebook
- Standard Chartered Bank
- Jane Street
Aims and Motivation (6)

- **Learning Outcomes:**
  - Knowledge of language and compiler design, semantics, key ideas and techniques.
  - Experience of compiler construction tools.
  - Experience of working with a medium-sized program.
  - Programming in various paradigms
  - Capturing design through formal specifications and deriving implementations from those.

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Literature (1)


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- Considers software engineering aspects.
- A bit weak on linking theory with practice.

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For each lecture, there are references to the relevant chapter(s) of both books (see lecture overview on the G53CMP web page).

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- *There is a New(-ish) 2007 edition!*
Other useful references:

- Benjamin C. Pierce. *Types and Programming Languages*.

G53CMP: Lecture 1 – p.13/38
Lectures and Handouts

- Come prepared to take notes. There will be some handouts, but for the most part not.
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**However!** The electronic record of the lectures is neither guaranteed to be complete nor self-contained!
Assessment (1)

First sit:

- The exam counts for 75% of the total mark.
- The coursework counts for the remaining 25%.
- 2 h exam, 3 questions, each worth 25%. (No optional questions: be aware of this if you look at past exam papers.)
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**Bonus!** There will be (sub)question(s) on the exam closely related to the coursework!

Effectively, the weight of the coursework is thus more like 50 %, except partly examined later.
Resit:

- The exam counts for 100% of the total mark.
- 2 h exam, 4 questions, each worth 25%
- *The coursework does not count.*
Assessment (3)

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Coursework (1)

Learning goals:

• Getting a practical understanding of key concepts and techniques in the fields of compiler construction and language theory.
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• Getting a practical understanding of key concepts and techniques in the fields of compiler construction and language theory.
• Getting hands-on experience of working with language processors.
• Getting some experience of using compiler construction tools.
• Getting experience of the issues involved in working with medium-sized programs.
Coursework (2)

You will be given partial implementations of a compiler for a small language called MiniTrinagle.

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Detailed instructions for the coursework available (soon) from the course web page.
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*Study these instructions very carefully!*
Haskell and Coursework Support (1)

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- Functional language notation is closely aligned with mathematical notation and formalisms (such as attribute grammars) commonly used in textbooks on compilers.
- A really good choice for implementing compilers in practice (and much else beside).
Haskell and Coursework Support (2)

To help you get up to speed using Haskell and provide some extra help with the coursework:
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- Haskell revision coursework (unassessed).
- Slides from a Haskell revision lecture via module web page.
Laboratory Sessions

Laboratory sessions:
- Tuesdays, 9–11, A32
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- TAs will be present during the laboratory sessions from 7 October.
Coursework Assessment (1)

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- Catch-up slots *only* if missed slot with good cause; personal tutor to request on your behalf.
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- Written answer to each question assessed on
  - Correctness (0, 1, or 2 marks)
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- In the oral examination (part II only), you explain your answers.
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- Written answer to each question assessed on
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  - Style (0, 1, or 2 marks)
- In the oral examination (part II only), you explain your answers.
- Your explanations are assessed as follows:
  - 2: 100% of mark for written answer
  - 1: 65% of mark for written answer
  - 0: 0% of mark for written answer
Coursework deadlines:

- Part I: Wednesday **29 October**, 16:00.
- Part II: Wednesday **26 November**, 16:00.
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Oral examinations during the lab sessions the following two Tuesdays; i.e. **2** and **9 December**.
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*Start early!* It is *not* possible to do this coursework at the last minute.
What is a Compiler? (1)

Compilers are *program translators*:

![Diagram of compiler process]

Typical example:

- Source language: C
- Target language: x86 assembler
What is a Compiler? (1)

Compilers are program translators:

Typical example:

- Source language: C
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Why? To make it easier to program computers!
What is a Compiler? (2)

GCC translates this C program

```c
int main(int argc, char *argv) {
    printf("%d\n", argc - 1);
}
```

into this x86 assembly code (excerpt):

```assembly
movl 8(%ebp), %eax
decl %eax
subl $8, %esp
pushl %eax
pushl $.LC0
call printf
addl $16, %esp
```
Source and Target Languages

Large spectrum of possibilities, for example:

- Source languages:
  - (High-level) programming languages
  - Modelling languages
  - Document description languages
  - Database query languages
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Large spectrum of possibilities, for example:

- **Source languages:**
  - (High-level) programming languages
  - Modelling languages
  - Document description languages
  - Database query languages

- **Target languages:**
  - High-level programming language
  - Low-level programming language (assembler or machine code, byte code)
Where are Compilers Used? (1)

- Implementation of programming languages: C, C++, Java, C#, Haskell, Lisp, Prolog, Ada, Fortran, Cobol, ...
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- Document processing: LaTeX → DVI, DVI → PostScript/PDF/...
- Databases: optimization of database queries expressed in query languages like SQL.
Where are Compilers Used? (2)

- Hardware design: modelling and simulation/verification, compilation to silicon. E.g. Spice, VHDL.
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- Interpreter: effectively translates (the used parts of) a source program every time it is run.
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- Compilers and interpreters sometimes used together, e.g. Java: Java compiled into Java byte code, byte code interpreted by a Java Virtual Machine (JVM), JVM might use JIT.
Traditionally, a compiler is broken down into several phases:

- **Scanner**: lexical analysis
- **Parser**: syntactic analysis
- **Checker**: contextual analysis (e.g., type checking)
- **Optimizer**: code improvement
- **Code generator**
Inside the Compiler (2)

- Lexical Analysis:
**Inside the Compiler (2)**

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  - Verify that input character sequence is lexically valid.
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  - Group characters into sequence of lexical symbols, *tokens*.
  - Discard white space and comments (typically).
Inside the Compiler (3)

- Syntactic Analysis/Parsing
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  - Verify that the input program is syntactically valid, i.e. conforms to the Context Free Grammar of the language.
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  - Verify that the input program is syntactically valid, i.e. conforms to the Context Free Grammar of the language.
  - Determine the program structure.
  - Construct a representation of the program reflecting that structure without unnecessary details, usually an Abstract Syntax Tree (AST).
Inside the Compiler (4)

- Contextual Analysis/Checking Static Semantics:
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  - Resolve meaning of symbols.
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- Optimization:
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- Contextual Analysis/Checking Static Semantics:
  - Resolve meaning of symbols.
  - Report undefined symbols.
  - Type checking.
  - ...

- Optimization:
  - Code improvements aiming at making it run faster and/or use less space, energy, etc.
  - Almost always heuristics: cannot guarantee optimal result.
Inside the Compiler (5)

- Code Generation:
Code Generation:
- Output the appropriate sequence of target language instructions.
Inside the Compiler (5)

- Code Generation:
  - Output the appropriate sequence of target language instructions.
  - Might involve further *low-level* (target-specific) optimization.
Inside the Compiler (6)

sequence of characters

**scanner**  
Lexical Analysis

sequence of tokens

**parser**  
Syntactic Analysis/Parsing

Abstract Syntax Tree (AST)

**checker**  
Contextual Analysis/checking Static Semantics  
(e.g. Type Checking)

Intermediate Representation (IR), e.g. verified/annotated AST

**optimizer/code generator**  
Optimization and Code Generation  
(possibly many steps involving a number of intermediary representations)

target code
Inside the Compiler (7)

- **Front end**: Scanner, Parser, Contextual checker. Depends more heavily on the *source language*.
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- **Middle section** ("Middle end"): Optimizer. Operates on an Intermediary Representation (IR) that could be fairly independent of source and target language. Hence potentially reusable!

- **Back end**: Code Generator Depends heavily on the *target language*. 