COMP3012/G53CMP: Lecture 1

Administrative Details 2018
and
Introduction to Compiler Construction

Henrik Nilsson

University of Nottingham, UK

Finding People and Information (1)

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- Teaching Assistants:

	`www.cs.nott.ac.uk/`
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Guerric Chupin	`~psxgc4`
Jennifer Hackett	`~psxjlha`

Finding People and Information (2)

- Main module web page:
  `www.cs.nott.ac.uk/~psznhn/G53CMP`

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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.

Notes on Lectures 2018

- Two lectures on Thursdays, 16:00–18:00

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- Always a break 16:50–17:00
- ***No lectures on 11 October!***

Aims and Motivation (1)

Why study Compiler Construction?

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- Why did you opt to take this module?
- More generally, what do you think are good reasons to take this module?

Aims and Motivation (2)

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- how compilers (and interpreters) work and are constructed
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The former is a great, “hands on”, “learning-by-doing” way to learn the latter.

Aims and Motivation (3)

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The ACM/IEEE 2013 CS Curriculum Guidelines:

“Graduates should realize that the computing field advances at a rapid pace, and graduates must possess a solid foundation that allows and encourages them to maintain relevant skills as the field evolves. Specific languages and technology platforms change over time. . . .

Aims and Motivation (3)

Why?

The ACM/IEEE 2013 CS Curriculum Guidelines:

. . . Therefore, graduates need to realize that they must continue to learn and adapt their skills throughout their careers. To develop this ability, students should be exposed to multiple programming languages, tools, paradigms, and technologies as well as the fundamental underlying principles throughout their education."

Aims and Motivation (4)

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- Formal Languages and Automata Theory
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- Formal reasoning about programs
- Software engineering aspects

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- Computer architecture
- Programming language semantics
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Thus, “capstone” module tying everything together.

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- Jane Street

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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- Hands-on approach to compiler construction. Particularly good if you like Java.
- 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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Great supplement: Alfred V Aho, Ravi Sethi, Jeffrey D. Ullman. *Compilers — Principles, Techniques, and Tools*, Addison-Wesley, 1986. (The “Dragon Book”.)

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- ***There is a New(-ish) 2007 edition!***

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Sure! They focus on core principles of lasting value that it pays off to learn.

Cf. ACM/IEEE 2013 Curriculum Guidelines

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- All *electronic* slides, program code, and other supporting material in *electronic* form used during the lectures, will be made available on the course web page.
- ***However!*** The electronic record of the lectures is neither guaranteed to be complete nor self-contained!

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- An ideal language for ***illustrating*** and ***discussing*** all aspects of compiler construction (and similar applications).
- Functional language notation is ***closely aligned with mathematical notation*** and formalisms used in text books on compilers.
- In practice, often a ***good choice for implementing*** compilers (and much else beside).

Assessment

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Resit: ***100 % exam***

Assessment (2)

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- Compiler construction is best learnt by doing.
- Thus, if you do and understand the coursework, you will be handsomely rewarded.
- Past experience shows that students who don’t engage with the coursework struggle to pass.

Coursework

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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
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  - Style (0, 1, or 2 marks)
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- 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

Coursework deadlines:

- Part I: Monday ***5 November***, 15:00.
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Oral examinations during the lab sessions the following two Fridays; i.e. ***7*** and ***14 December***.

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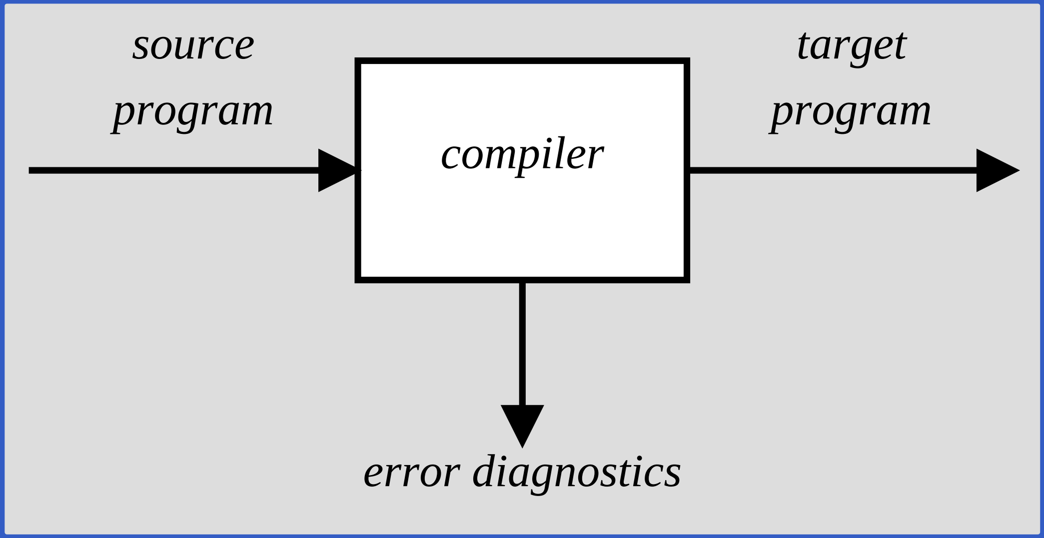
Start early! It is ***not*** possible to do this coursework at the last minute.

First lab session: Friday 19 October, 13:00–15:00.

What is a Compiler? (1)

Compilers are ***program translators***:



Typical example:

- Source language: C
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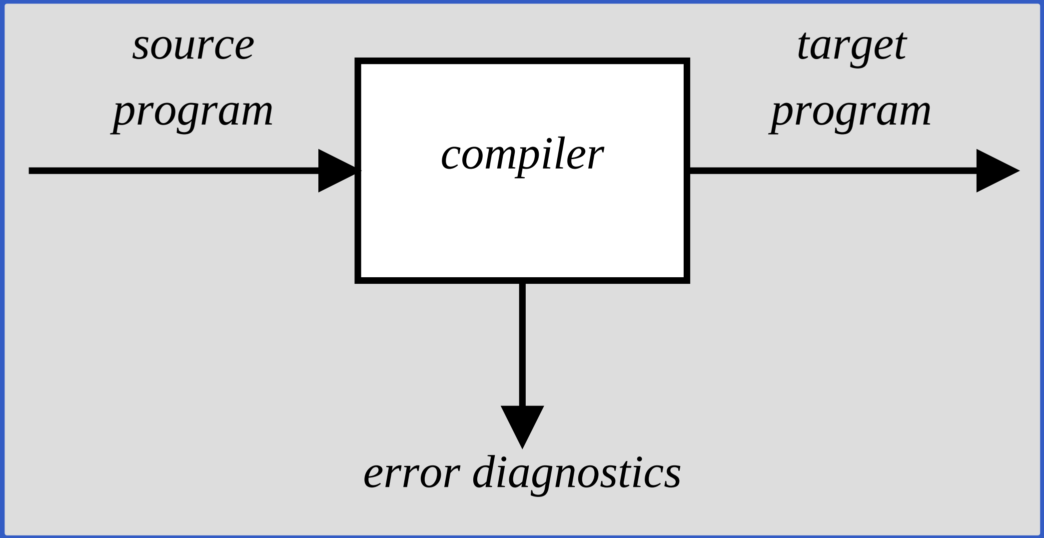

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Why? To make it easier to program computers!

What is a Compiler? (2)

GCC translates this C program

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

into this x86 assembly code (excerpt):

```
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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- 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)

Compilers vs. Interpreters

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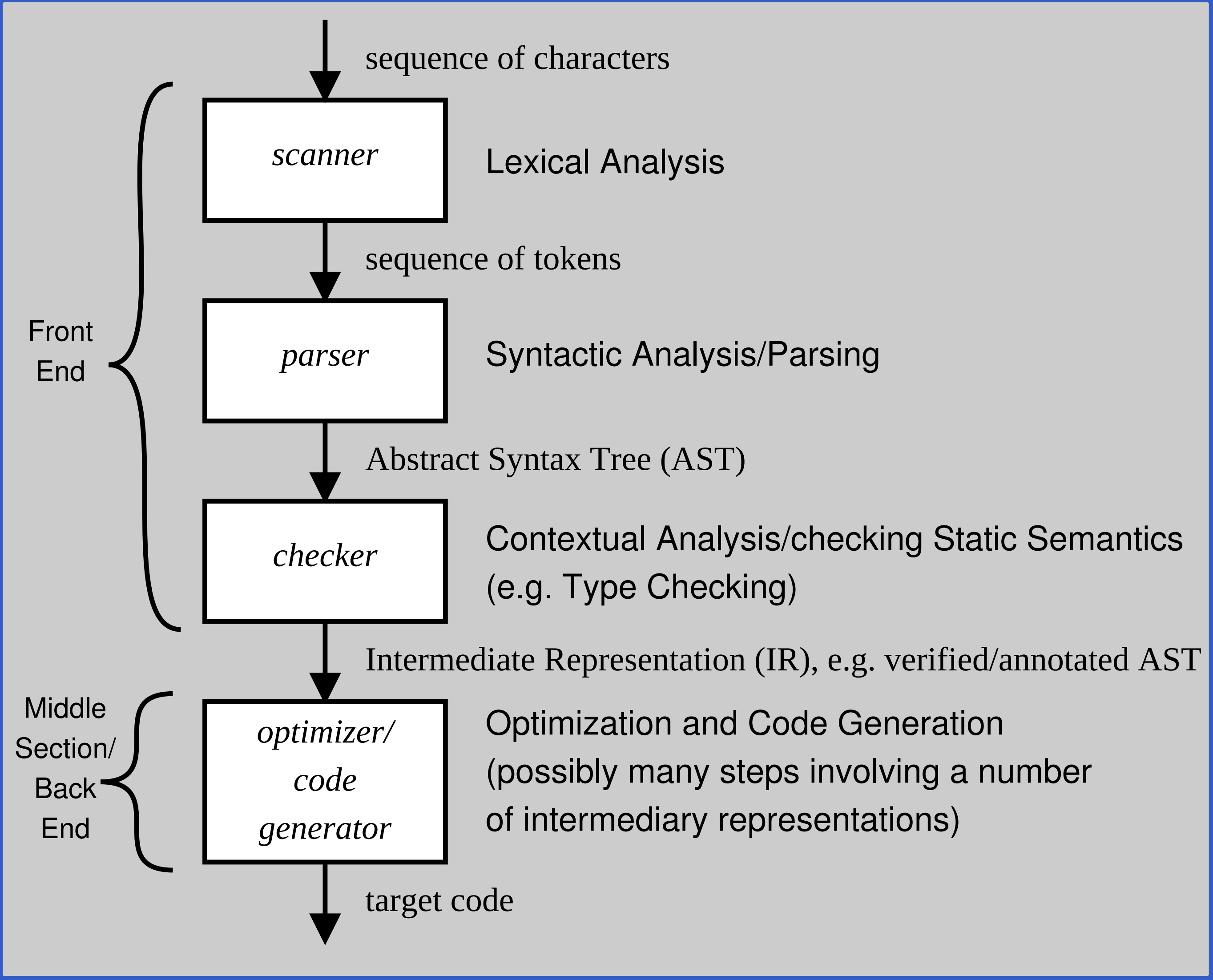
- Interpreter: effectively translates (the used parts of) a source program every time it is run.
- Techniques like ***Just-In-Time Compilation*** (JIT) blurs this distinction.
- Compilers and interpreters sometimes used together, e.g. Java: Java compiled into Java byte code, byte code interpreted by a Java Virtual Machine (JVM), JVM might use JIT.

Inside the Compiler (1)

Traditionally, a compiler is broken down into several phases:

- ***Scanner***: lexical analysis
- ***Parser***: syntactic analysis
- ***Checker***: contextual analysys (e.g. type checking)
- ***Optimizer***: code improvement
- ***Code generator***

Inside the Compiler (2)



Inside the Compiler (3)

- Lexical Analysis:
  - Verify that input character sequence is lexically valid.
  - Group characters into sequence of lexical symbols, ***tokens***.
  - Discard white space and comments (typically).

Inside the Compiler (4)

- Syntactic Analysis/Parsing
  - 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).

Example: TXL into C compiler

Scenario:

- We wish to develop a compiler for TXL: *Trivial eXpression Language*.

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Scenario:

- We wish to develop a compiler for TXL: *Trivial eXpression Language*.
- To save ourselves some effort, we are going to compile TXL into C, and then use an existing C compiler (GCC) to translate into executable machine code.

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Some examples of TXL programs, ***concrete syntax***, and their intended meaning, ***semantics***:

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  Semantics: *24*

This is ***dynamic semantics***: what does a program mean when run?

Inside the Compiler (5)

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

Informal TXL Syntax and Semantics

- `let x = 3 * 7 in let x = x * 3 in x - 21`

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Informal TXL Syntax and Semantics

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- Catch use of undefined variables ***dynamically***, making the meaning of the program ***undefined***.
- Assume some default value, like 0, for variables that are not explicitly defined.

Inside the Compiler (5)

- Optimization:
  - Code improvements aiming at making it run faster and/or use less space, energy, etc.
  - Almost always ***heuristics***: cannot ***guarantee*** optimal result.
- Code Generation:
  - Output the appropriate sequence of target language instructions.
  - Might involve further ***low-level*** (target-specific) optimization.