COMP2012/G52LAC
Languages and Computation
Lecture 1

Administrative Details and Introduction

Venanzio Capretta and Henrik Nilsson

University of Nottingham

Finding People and Information

- Venanzio Capretta
  Room C05
- Henrik Nilsson
  Room A08
- Moodle
- Main module web page:
  `www.cs.nott.ac.uk/~nhn/COMP2012`
- Moodle forum!

Aims of the Course

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- To familiarize you with key Computer Science ***concepts*** in central areas:
  - Automata Theory
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  - Models of Computation
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Draws from: COMP1001/G51MCS
Feeds into: COMP3012/G53CMP, COMP3001/G53COM, COMP4001/G54FOP

Organization (1)

- ***Lectures:***
  - Two 1 h lectures per week (back to back).
  - Detailed but provisional schedule available on the module web page.

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- ***Coursework:***
  - 3 problem sets.
  - Made available via the module web page.
  - Best 2 counts.
  - Deadlines: 27/2, 20/3, 10/4.
  - Released a week prior to submission deadline.

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- ***Assessment:***
  - Coursework, 25 %
  - 2 hour written examination, 75 %

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  - 2 hour written examination, 75 %
- However, ***resits*** are by 100 % written examination (standard School policy)

Literature (1)

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- Alternative/complement: Linz. *An Introduction to Formal Languages and Automata, 6th edition*, Jones & Bartlett Publishers, 2017.
- The lecture notes by Altenkirch, Capretta, Nilsson (January 2019).
  Available via the module web page.

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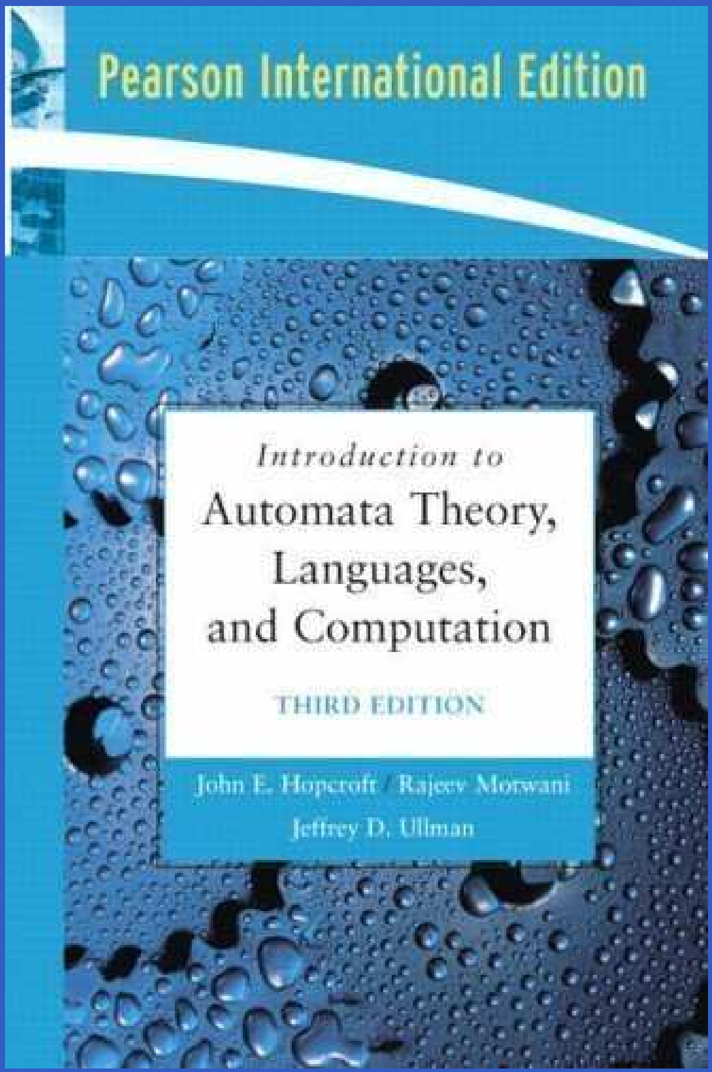
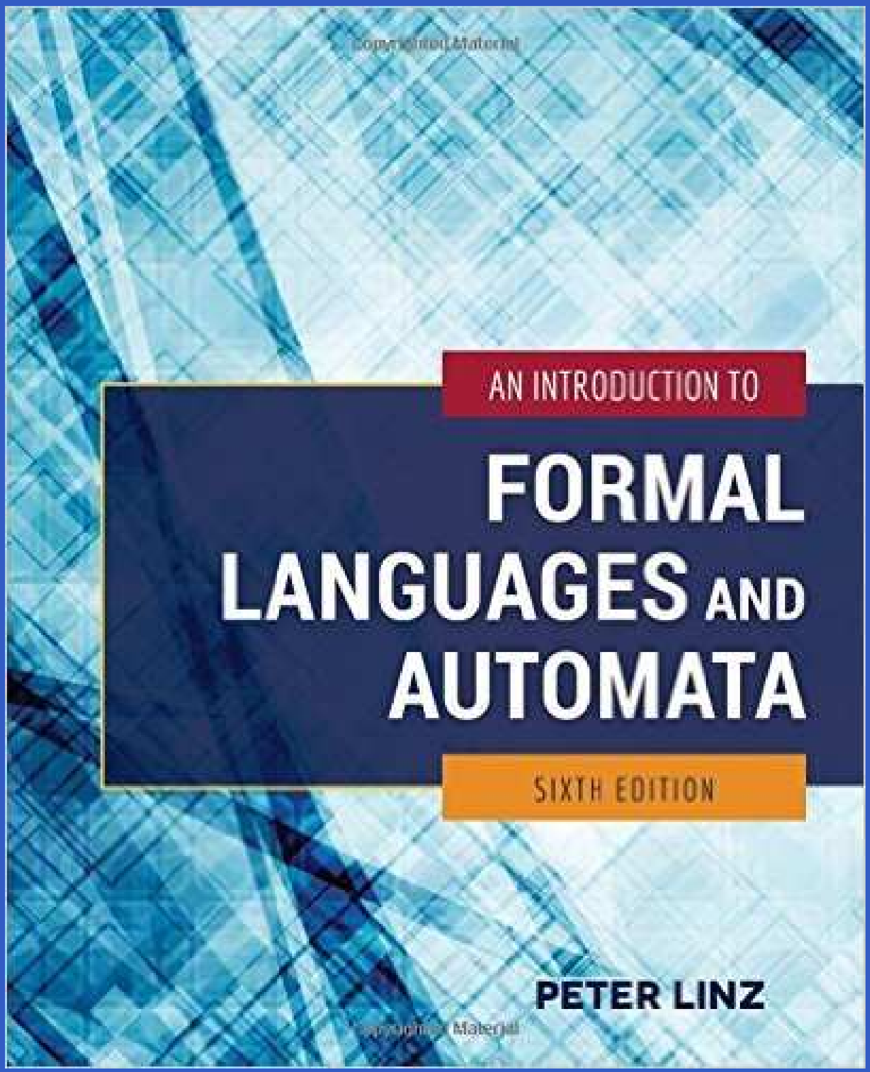
- The lecture schedule contains detailed lecture-by-lecture references to the literature.

Literature (3)





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- The exercises are quite similar to typical coursework problems.

Your Own Notes

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Taking relevant notes is a lot easier if you familiarise yourself with the relevant parts of the typeset lecture notes prior to each lecture!

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- Applications: Scanning and Parsing

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- General notions of computation:
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  - Lambda calculus
- Fundamental questions such as
  - What can be computed at all?
  - What can be computed efficiently?

Example: Languages and Grammars (1)

Consider the following Java fragment:

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- Fundamentally a string of characters.
- But lots of structure to valid Java code, e.g.:
  - Keywords, identifiers, operators
  - Nesting; e.g. method inside class

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- Various kinds of ***automata***: decide if a string belongs to a language or not.

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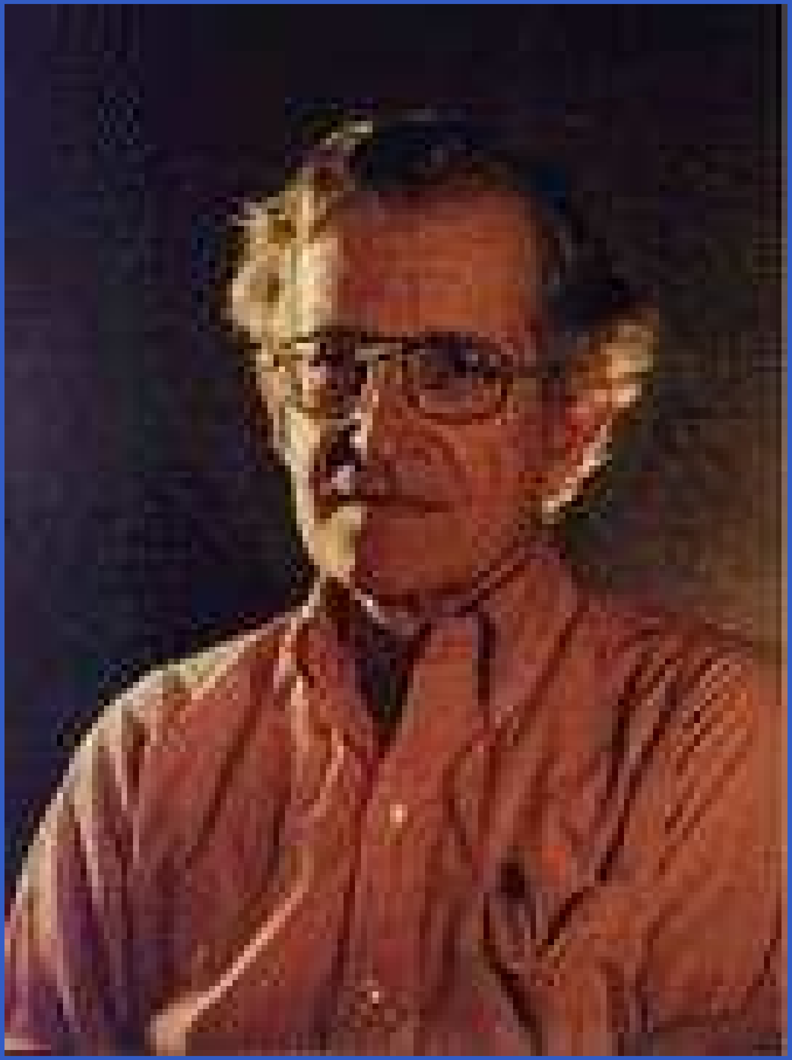
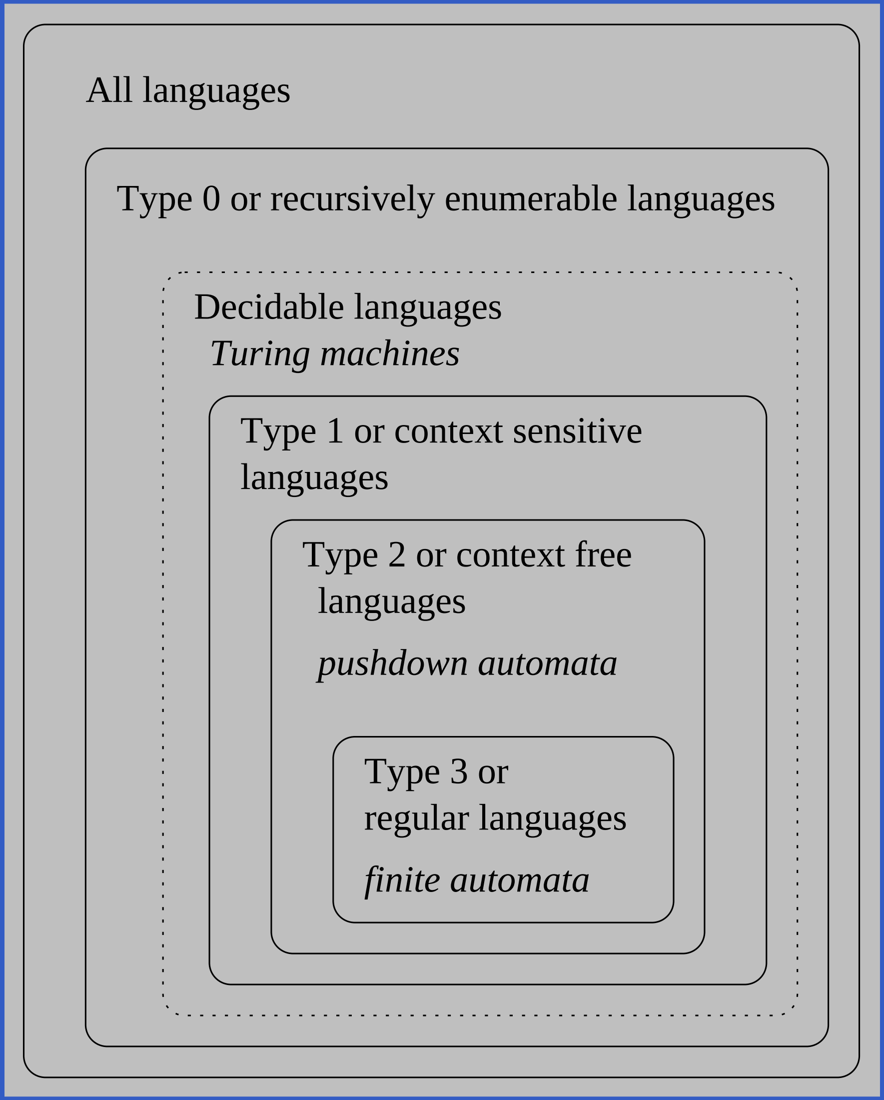
- American linguist who introduced ***Context Free Grammars*** in an attempt to describe natural languages formally.
- Also introduced the ***Chomsky Hierarchy*** which classifies grammars and languages and their descriptive power.

Noam Chomsky (2)



The Chomsky Hierarchy



Example: The Halting Problem (1)

Consider the following program. Does it terminate for all values of $n \geq 1$?

```
while (n > 1) {
    if even(n) {
        n = n / 2;
    } else {
        n = n * 3 + 1;
    }
}
```

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. . . but so far, ***no proof***! (See e.g. Wikipedia.)

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This was first proved by the British mathematician ***Alan Turing*** using Turing Machines.

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- Functional programming languages like Haskell implements the λ-calculus.
- Both the Turing machine and the λ-calculus are ***universal models of computation***: equivalent in capabilities.

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- Introduced the ***λ-calculus*** (1936) to give a precise definition of what problems are "effectively calculable".
- Church-Turing thesis: What is "effectively calculable" is exactly what can be computed by a Turing machine.

Alonzo Church (2)

Example: P versus NP (1)

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- Likely the most famous open problem in computer science, dating back to the 1950s.
- "Quickly" here means in time proportional to a ***polynomial*** in the size of the problem.
- There is an abundance of important problems where solutions can be checked quickly, but where the best ***known*** algorithm for finding a solution is ***exponential*** in the size of the problem.

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- But for finding a solution, no better way known than essentially trying each possible subset in turn. (How long would it take for set of size n? How many subsets are there?)

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The term ***string*** is often used interchangeably with the term ***word***.

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ϵ, the empty word, is ***never*** a symbol of an alphabet.

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alphabet	$\Sigma = \{a, b\}$
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Note the distinction between ϵ, $\emptyset$, and $\{\epsilon\}$!

All Words Over an Alphabet (1)

Given an alphabet Σ we define the set Σ^* as set of words (or sequences) over Σ:

- The empty word $\epsilon \in \Sigma^*$.
- given a symbol $x \in \Sigma$ and a word $w \in \Sigma^*$, $xw \in \Sigma^*$.
- These are all elements in Σ^*.

This is called an ***inductive definition***.

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Is Σ^* always non-empty? Always infinite?

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Example: Given $\Sigma = \{0, 1\}$, some elements of Σ^* are

- ϵ (the empty word)
- $0, 1$
- $00, 10, 01, 11$
- $000, 100, 010, 110, 001, 101, 011, 111$
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Note: although there are infinitely many words in Σ^* (when $\Sigma \neq \emptyset$), each word has a ***finite*** length!

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- The set of words that contain the same number of 0s and 1s is a language over $\Sigma = \{0, 1\}$. (Finite or infinite?)

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- The set of correct Java programs. This is a language over the set of UNICODE characters.
- The set of programs that, if executed successfully on a Windows machine, prints the text “Hello World!” in a window. This is a language over $\Sigma = \{0, 1\}$.

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- A ***finite*** (and preferably concise) formal ***description*** of L.
- An algorithmic ***method to decide*** if $w \in L$ given a suitable description.

Various approaches to achieve this will be key a theme throughout the module.