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IN2009  
Language Processors

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Week 1

## Introduction to Language Processors & Recap of Java

From code to action

Christian Cooper

## Who am I?

- Christian Cooper
- Visiting Lecturer
  - University Teaching Fellow at TVU
- Situated in A401 (the mezzanine above the school office)
- [chi@soi.city.ac.uk](mailto:chi@soi.city.ac.uk)
- Teaching **IN2009 Language Processors** this semester.



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## Ground Rules

Please:

- Arrive on time (all lectures start on the hour, so come in and sit down a few minutes early).
- Switch off 'phones, alarms etc.
- Ask questions.

Please **DON'T**:

- Chat in the background.
- Text message/play phone games/etc.

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## Audio/Video recording of classes

- My policy:
- You are free to use a Dictaphone or similar to record the audio of my lectures/labs...
  - ...so long as you give me the courtesy of asking me first; I rarely refuse permission.
- Video recording of lectures and labs is generally **not** permitted (without good reason).

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## Dates for your diary...

- Lectures (10):
  - Weeks 1-5, 7-11.
  - No lecture weeks 6 and 12.
- Labs (10):
  - **Start this week!**
  - Weeks 1-5, 7-11.
  - No labs weeks 6 and week 12.

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## What's in store this week

### Week 1

- Module details, aims, resources
- What is language processing and implementation?
- Syntax definition
- Straight-line programming language
- Abstract syntax trees
- Some Java reminders...

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## Module Details

- **Module Leader - Prof. David Bolton**
  - But please contact *me* in the first instance for any day-to-day queries...
- **Support**
  - The primary form of support is during the lab sessions.
  - Supported by **Kamal Pal**, and occasionally me.
  - Admin support is from **Heather Wilson**.

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## Module Details

- **Support (con't)**
  - Online support is through Cityspace:  
<http://www.city.ac.uk/cityspace>
  - Use the discussion boards well!
  - e-mail should be seen as a last resort; unless it is discussing purely personal issues, it will simply be anonymised and cut & paste into the discussion boards on Cityspace!
  - ...with up to a week's delay!

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## Module Details

- **Rationale**
- “Most computer programs process input whose structure is expressible in a language definition. Such input includes programming languages themselves, of course.”

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## Module Details

- “An understanding of how to write such definitions, and how to turn a definition into a recogniser and translator for the language, will give students an understanding of programming language structure and implementation that will compliment programming skills and aid the learning of new programming languages.”

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## Module Details

- “Also, an understanding of the run-time environment for the translated program will give insight into how high-level programs execute at machine level.”

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## Module Aims

- “To introduce students to the **specification** and **implementation** of programming languages. In particular the module aims to provide an introduction to the **structure** of programming languages, the **algorithms and data structures** used in compilers, the tools which may be used to **automate** compiler construction, and to the **run time environments** in which programs execute.”

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## Indicative Content

- Syntax definition using regular and context free grammars
- Abstract and concrete syntax, and abstract syntax tree representations
- Introduction to type-checking
- Translation
- Runtime environments

## Core Text

- Appel, A., "*Modern Compiler Implementation in Java*", 2nd ed., 2002, Cambridge University Press, ISBN-13: 978-0521820608

Appel (2002)



## Learning Outcomes

- On successful completion of this module, you will be able to:
  - Use formal languages to define input language syntax.
  - Explain techniques for syntactic and semantic analysis and translation.
  - Explain the compiled code, and run-time environment requirements, for various common programming language structures.
  - Program data structures and algorithms for representation and analysis and translation of programming languages.
  - Use standard compiler generation tools.

## Assessment

- In-module coursework tasks
  - 2 practical assessments (weeks 4 - 11).
  - 30% of module marks (12%, 18%).
  - Pair working is allowed, but you **must** declare if you do so! More on this at a later date.
- End-of-module exam
  - Unseen, written 1.5-hour paper.
  - 70% of module marks (*min threshold 30%*).
  - In May 2008.

## Coursework

- The first assessment brief will be published on Cityspace next week.
- Deadlines:
  - All deadlines are by **5pm** on **Friday** of the indicated week.
  - Assessment 1, part 1 (*RegExp*): Week 4
  - Assessment 1, part 2 (*Analysis*): Week 7
  - Assessment 2 (*Type Checking*): Week 12

## Coursework

- (*From the student handbook*)
- **4.4.7. Lateness Penalties**
- If you hand in a piece of coursework after 5pm on the deadline date it will be marked as late.
- Lecturers will apply a late penalty of up to 10 marks per day. Therefore assignments received 10 days or more past the deadline will receive a mark of 0.

## A note on Plagiarism

- Plagiarism is the failure to acknowledge any work which is not 100% your own.
- This includes undeclared “group working” on assessments.
  - You are permitted to work as a pair in the first coursework, but you must declare this (and tell me who your partner was for each submitted exercise). Groups of three and more is not allowed.
- Plagiarism leads to a formal hearing!

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## Coursework

- Coursework marks and feedback will be returned to you via Cityspace.
  - Usually within two weeks of the deadline.
- It is my intention to produce a guideline answer for all assessments - published around 3 weeks after each deadline.
  - Not a “model” solution, but one which is fit for purpose and would have achieved approximately 50-60%

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## Structure of the lectures

- This week serves as an introduction to the topic, and will also focus on a brief recap of Java.
  - This is the only time I will focus on Java and programming from a “learning a language” perspective rather than “compiling a language” - I expect you to revise Java in your own time this week, and to practice if you do not feel 100% confident with the language!

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## Structure of the lectures

- Including this week, there are 9 lectures focussing on aspects of language processing, organised into 8 logical learning blocks
  - “Sessions”
  - Some sessions may span multiple lectures.
- The final week’s lecture will focus on reviewing the module, considering revision and working on past papers.

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## Structure of the lectures

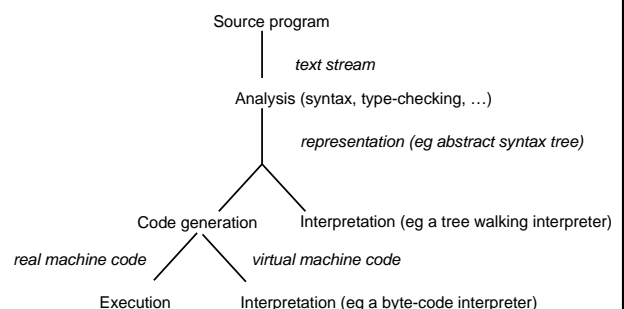
- 1. Introduction to Language Processing** (this week)
- 2. Language processing & lexical analysis** (next week!)
- 3. Parsing I (syntax analysis)**
- 4. Parsing II (abstract syntax)**
- 5. MiniJava abstract syntax trees**
- 6. Semantic analysis**
- 7. Activation records (stack frames)**
- 8. Translation to intermediate representation**

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## Language processing & implementation

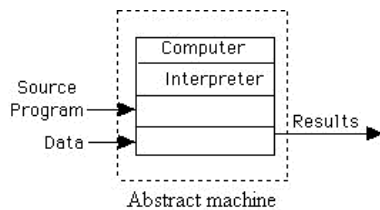


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## Pure interpreter



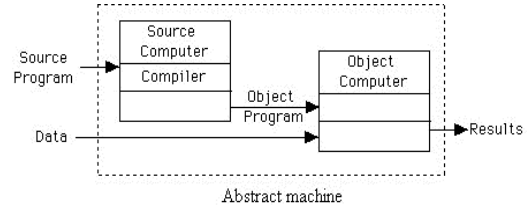
- Programming language, plus computer and interpreter, provides an abstract (or virtual) machine for the programmer.

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## Pure compiler



- Programming language plus compiler and computer provides an abstract machine.

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## Pure compiler

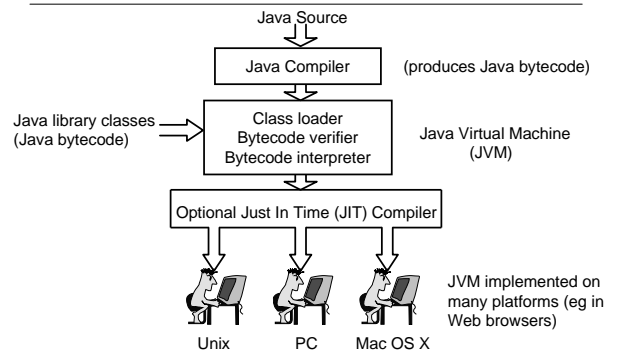
- But only rarely do we have a pure interpreter or compiler.
- Typically code is first compiled to *intermediate* form.
- Then...
  - interpreted, or
  - code generated for a virtual machine interpreter or for a real machine

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## Example: Java implementation



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## What we will do in this module...

- Work through Appel (2002)
  - Leaving out much of the theory
- Define a simple programming language
- Implement some example abstract trees for the simple programming language
- Introduce a more complicated language
- Implement a lexical analyser using JavaCC

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## What we will do in this module...

- Implement a syntax analyser using JavaCC
- Implement an abstract syntax tree builder
- Look at semantic analysis (eg type-checking)
- Look at runtime environments and translation

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## Syntax definition

- Use context-free grammars (e.g. Backus–Naur Form or **BNF**) to define a grammar for the language

```

Stm   →   id := Exp | ifStm | ...
ifStm →   if Exp then Stm | if Exp then Stm else Stm
Exp   →   id | num | Exp Binop Exp | ...

```

| "or" - separates alternatives  
 → "is defined as"  
 ifStm, Stm non-terminals  
 if, id, num, := terminals (tokens)

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## Syntax definition

- Each definition is called a production; many productions define a grammar
- Repetition by recursive definition
- You may have seen BNF before...
  - ...any MySQL users? The manual and instruction list shows the statement syntax in BNF.

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## Syntax definition

```

<syntax> ::= <rule> | <rule> <syntax>
<rule>   ::= <opt-whitespace> "<" <rule-name> ">"
           <opt-whitespace> "::="
           <opt-whitespace> <expression>
           <line-end>
<opt-whitespace> ::= " " <opt-whitespace> | ""
<expression> ::= <list> | <list> "|" <expression>
<line-end> ::= <opt-whitespace> <EOL>
              | <line-end> <line-end>
<list> ::= <term>
           | <term> <opt-whitespace> <list>
<term> ::= <literal> | "<" <rule-name> ">"
<literal> ::= "'" <text> "'" | '"' <text> '"'

```

- (From Wikipedia - guess what this BNF is for?)

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## Straight-line programming language

```

Stm   →   Stm ; Stm           (CompoundStm)
Stm   →   id := Exp           (AssignStm)
Stm   →   print ( ExpList )   (PrintStm)
Exp   →   id                   (IdExp)
Exp   →   num                  (NumExp)
Exp   →   Exp Binop Exp       (OpExp)
Exp   →   ( Stm , Exp )       (EseqExp)
ExpList → Exp , ExpList       (PairExpList)
ExpList → Exp                 (LastExpList)
Binop → +                     (Plus)
Binop → -                     (Minus)
Binop → ×                     (Times)
Binop → /                     (Div)

```

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## Straight-line programming language

```

Stm   →   Stm ; Stm | id := Exp | print ( ExpList )
Exp   →   id | num | Exp Binop Exp | ( Stm , Exp )
ExpList → Exp , ExpList | Exp
Binop  →   + | - | × | /

```

- A program (what does it do?):

```

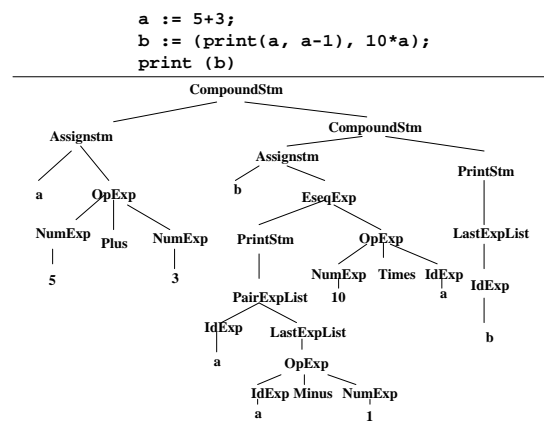
a := 5+3;
b := (print(a, a-1), 10*a);
print (b)

```

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## Java representation of the abstract syntax

```
static Stm prog =
new CompoundStm(new AssignStm("a",new OpExp(new NumExp(5),
    OpExp.Plus, new NumExp(3))),
new CompoundStm(new AssignStm("b",
    new EseqExp(new PrintStm(new PairExpList(
        new IdExp("a"),
        new LastExpList(new OpExp(new IdExp("a"),
            OpExp.Minus, new NumExp(1))))) ,
    new OpExp(new NumExp(10), OpExp.Times,
        new IdExp("a")))),
    new PrintStm(new LastExpList(new IdExp("b")))));
```

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## Java abstract syntax representation: Program 1.5

```
abstract class Stm {}

class CompoundStm extends Stm {
    Stm stm1, stm2;
    CompoundStm(Stm s1, Stm s2) {stm1=s1; stm2=s2;}
}

class AssignStm extends Stm {
    String id; Exp exp;
    AssignStm(String i, Exp e) {id=i; exp=e;}
}

class PrintStm extends Stm {
    ExpList exps;
    PrintStm(ExpList e) {exps=e;}
}
```

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## Java abstract syntax representation: Program 1.5

```
abstract class Exp {}

class IdExp extends Exp {
    String id;
    IdExp(String i) {id=i;}
}

class NumExp extends Exp {
    int num;
    NumExp(int n) {num=n;}
}

class OpExp extends Exp {
    Exp left, right; int oper;
    final static int Plus=1,Minus=2,Times=3,Div=4;
    OpExp(Exp l, int o, Exp r) {left=l; oper=o; right=r;}
}
```

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## Java abstract syntax representation: Program 1.5

```
class EseqExp extends Exp {
    Stm stm; Exp exp;
    EseqExp(Stm s, Exp e) {stm=s; exp=e;}
}

abstract class ExpList {}

class PairExpList extends ExpList {
    Exp head; ExpList tail;
    public PairExpList(Exp h, ExpList t) {head=h; tail=t;}
}

class LastExpList extends ExpList {
    Exp head;
    public LastExpList(Exp h) {head=h;}
}
```

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## maxargs and interp

- `int maxargs(Stm s)` returns the maximum number of arguments of any print statement within any subexpression of a given statement in a Straightline program.
  - `maxargs(prog)` returns 2
  - remember that print statements can contain expressions that contain other print statements
- `void interp(Stm s)` “interprets” a program written in the Straightline language

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## What you should do now...

- Read, digest and understand these slides!
  - in particular work out how you would write `maxargs(Stm s)` - I will give you `interp(Stm s)`, which is much harder...

```
class interp {
    static void interp(Stm s) { /* you write this part */ }

    static int maxargs(Stm s) { /* you write this part */
        return 0;
    }

    public static void main(String args[])
        throws java.io.IOException {
        System.out.println(maxargs(prog.prog));
        interp(prog.prog);
    }
}
```

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## Java recap - “datablast I”

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- The basics:
  - objects, classes, primitive data types, method invocation, attributes, parameters, return values/types, fields, constructors, mutator vs. accessor, variables, assignment, object references, selection (**if** statements), basic iteration (**while/for** loops), class diagrams, string manipulation, basic arithmetic and comparison, **public** vs **private**, using a debugger, commenting, class documentation, using API libraries, arrays, collections, hashes, **iterator**, basic testing...

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## Java recap - “datablast” II

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- Designing Classes & O-O concepts:
  - Cohesion, coupling, refactoring, subtyping, overriding, polymorphism, abstract classes
- GUI programming in **JSwing**, Inheritance, Java **interface**, Event-driven programming, layout managers, Errors, Exceptions, File handling, serialisation...

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## Java recap - doing without BlueJ

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- It is also time for us to do away with the “training wheels” and develop without BlueJ holding our hands.
- This is easier than it might seem;
- Our main program needs an **entry point** - which is the method **main()**:
  - **public static void main(String args[])**
- This method needs to set up and construct your initial objects, and then that is it!

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## Required reading for Week 2

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- Before next week’s labs and lecture you should read the following:
  - Appel (2002), ch. 1-2.

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## Next Lecture

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- *Language processing & lexical analysis*
- Monday 28th January, 2008
  - 11:00 - 12:50
  - C.348

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