School of Electrical Engineering and Computing

SENG2200/6220 PROGRAMMING LANGUAGES & PARADIGMS

(S1, 2020)

Introduction

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THE UNIVERSITY OF NEWCASTLE AUSTRALIA

Outline

- Course Introduction
- Java Review
- Preliminaries
- UML

Course Organisation

Lectures

Monday	15:00 – 17:00 @ HPE203

Labs

Monday	17:00 – 19:00 @ ES138
Thursday	09:00 – 11:00 @ ES138
Thursday	11:00 – 13:00 @ ES138
Thursday	14:00 – 16:00 @ ES138

(No labs in Week 1, 8 and 13)

Consultation Times

Lecturer: Dr. Nan Li

Office: ES222

Email: Nan.Li@newcastle.edu.au

Phone: 4921 6503

Consultation Times

Thursday: 12:00 – 14:00

Other Teaching Staff

- Mr. Daniel Bell
  - *Email: daniel.p.bell@newcastle.edu.au*
  - *Demonstrator and Marker*

Contact

- Discussion Forum
- Consultation time
- Email
    - *It is the **preferred** method if the forums and consultation time do not suit you.*

What is about the course?

- What will be covered?
  - *Object-Oriented Programming (OOP) topics*
  - *Memory management*
  - *Parameter-passing methods*
  - *Concurrency*
  - *Functional and logical programming*
- Knowledge required
  - *Data Structure*
  - *UML*
  - *Programming: Java and C/C++*

Course Objectives

On successful completion of this course, students should be able to

- Use Elementary Language Theory and Specification to describe language features.
- Program using advanced features of object-oriented languages.
- Compare the low level implementation of language mechanisms, such as pointers and references, activation records, method tables, memory allocation/de-allocation and garbage collection, thread activation and communication.
- Compare and analyse alternate parameter passing mechanisms.
- Describe the operation of non-object programming paradigms.

Contents

Week	Topic	Assessment
1	Introduction & Review	A1 out
2	Memory Management	
3	Inheritance	
4	Polymorphism	A1 due
5	Generics	A2 out
6	Iterators	
7	-	Midterm Test
8	Parameter-Passing	A2 due
9	Concurrency	A3 out
10	Functional Programming I	
11	Functional Programming II	
12	Logical Programming	A3 due
13	Revision	

Note: The order of topics and due date of assignments are subject to change.

Assessments

	Assessment Name	Due Date	Involvement	Weighting
1	Assignment 1 – Programming	Week 4	Individual	10%
2	Assignment 2 – Programming	Week 8	Individual	15%
3	Assignment 3 – Programming	Week 12	Individual	15%
4	Midterm Test	Week 7	Individual	10%
5	Formal Examination*	EXAM PERIOD	Individual	50%

References

- RW Sebesta, Concepts of Programming Languages, 10e, Pearson, 2012. ISBN 13:978-0-13-139531-2

Part 1 - Java Review

Overview

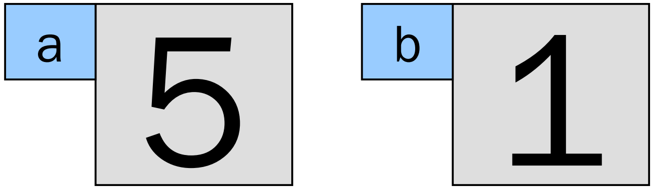
- What does this course expect you to know about Java?
    - *Control Structures (all).*
    - *What is a reference? What is a primitive data item? Why?*
    - *How do procedures/functions, parameter passing, and return values work for primitives and references?*
    - *Classes: declaration, instantiation, initialization, access, update.*
    - *Arrays: declaration, instantiation, access and update.*
- What things out of SENG1120 will be of help?
    - *Basic knowledge of data structures eg linked lists, stacks, queues.*
    - *Knowledge of C++ templates and basic memory management an advantage*
- Where to from here?
    - *We will advance your knowledge of Java.*
    - *We will re-do a reasonable amount of C++.*
    - *Expanding O-O concepts to include Inheritance, Abstract Classes, Pure Abstract Classes and Interfaces, comparing Java and C++ as we go.*

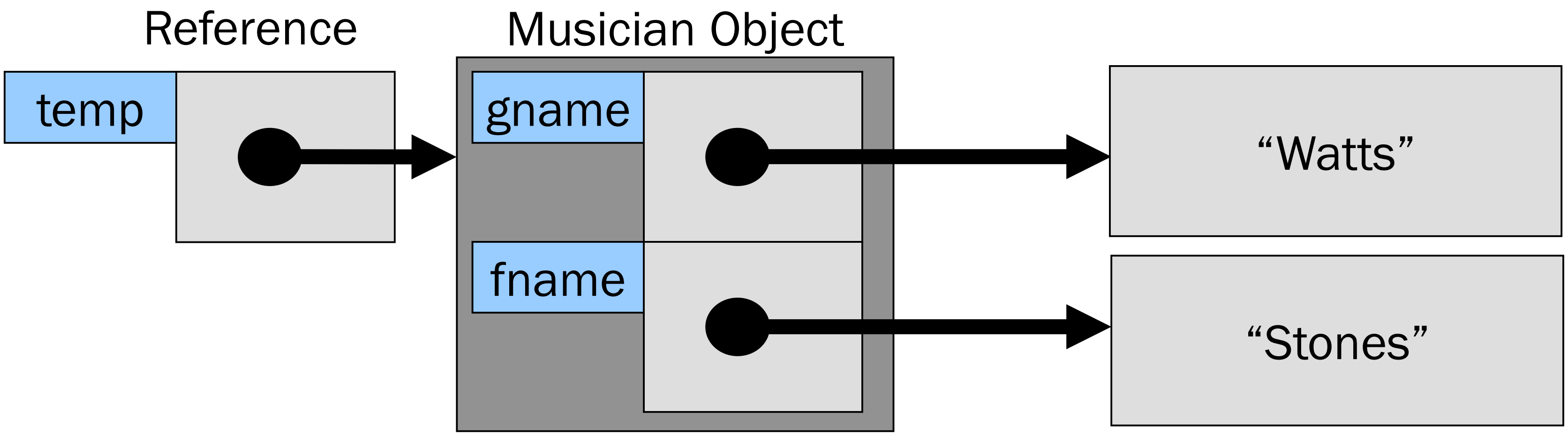
Control Structures

- Assignment and Evaluation
- If-Else
- While and Do-While
- For
- Switch Case Break Default
- Try Catch

Primitive Data and References

```
// Compare the actions taken when
int a=1, b = a; a = 5;
// with those when
Musician drums = new Musician(”Watts”,”Stones”);
Musician temp = drums;
```





Evaluation

- What does each of the operators do?

  `+  -  *  /  %  <  >=  >  <=  ==  !=`

- What else do we have to take into account here?

Functions: Parameters and Return values

```
int procN1(int p1,int p2,int p3){     //Compare
     int i = 0, j = 0, k = 1;
     ….
     return k;
}
Student procN2(Student s1,Student s2){//with
     Student t1, t2;
     …
     return t2;
}
```

- What does each function assume about data from the caller?
- Describe in detail what happens to each variable and return value during each of the function calls.

Classes and Static Data/Methods

- What does it really mean for data to be static in Java?

```
private static int numberOfAccounts = 0;

public static int getCount( ) {
    return numberOfAccounts;
}
```

- When do you use static data and static methods within a class?
- Java and C++ use and implement static data and methods in similar ways, but C++ uses the keyword `static` in extra (non-O-O) ways.

Arrays

- What are the steps in setting up an array?
  - *Declaration*
  - *Allocation*
  - *Initialization*

```
int[]  arr1;
int[]  arr2 = new int[5];
Student[] arr3, arr4;
```

- *How to access/update these arrays?*
- *What happens with the statements:*

```
arr1 = arr2; arr1[2]=arr2[1];  // and
arr3 = arr4;     arr3[0] = arr4[1];
```

Exceptions

▪ What is an exception in Java?	An Object (special)
▪ When it is used?	Unexpected event
▪ For what purpose?	Notifying the event
▪ What sort of mechanism is this really?	Procedure escape

- Do you know how to catch/throw exceptions?

Prelude to C++

- C++ was developed from C.

  "C with O-O extensions." – Bjarne Stroustrup.

- Java was developed under heavy influences from C++, it was made completely O-O and also was developed under the need to easily access the Internet.

- Learning C++?
  - *If you find it difficult to learn C++ then you are more likely to have misunderstood the O-O concepts in Java, rather than C++ itself being too difficult.*

Where to from here?

- How Java does Linked Structures
- How Java and C++ allow for Software Reuse
- How Java and C++ allow for Software Extensibility

Which of the following make you anxious?

What can you remember from your previous programming experiences?

- Can you write a Student class in Java?
- Can you instantiate an array of Student objects?
- Can you search that array for a particular Student?
- Can you write a Student class in C++?
- Can you write a doubly linked list template class for C++?
- Can you use it to construct a doubly linked list of Student objects?
- Can you pass both your array and your linked list as a parameter to a method (in their respective language)?
- Can you construct your array or linked list within a method and return it as the result of the method?

Part 2 - Preliminaries

Reasons for Studying Concepts of Programming Languages

- Increased ability to express ideas
- Improved background for choosing appropriate languages
- Increased ability to learn new languages
- Better understanding of the significance of implementation
- Overall advancement of computing

Programming Domains

- Scientific applications
  - *Large number of floating point computations*
  - *Fortran*
- Business applications
  - *Produce reports, use decimal numbers and characters*
  - *COBOL*
- Artificial intelligence
  - *Symbols rather than numbers manipulated*
  - *LISP*
- Systems programming
  - *Need efficiency because of continuous use*
  - *C*
- Web Software
  - *Eclectic collection of languages: markup (e.g., XHTML), scripting (e.g., PHP), general-purpose (e.g., Java)*

Language Evaluation Criteria

- Four evaluation criteria
  - *Readability*
  - *Writability*
  - *Reliability*
  - *Cost*
- Language Characteristics
  - *Simplicity*
  - *Orthogonality*
  - *Data Types*
  - *Syntax Design*
  - *Support for Abstraction*
  - *Expressivity*
  - *Type Checking*
  - *Exception Handling*
  - *Restricted Aliasing*

Language Evaluation Criteria

Table 1.1 Language evaluation criteria and the characteristics that affect them

	CRITERIA		
Characteristic	READABILITY	WRITABILITY	RELIABILITY
Simplicity	•	•	•
Orthogonality	•	•	•
Data types	•	•	•
Syntax design	•	•	•
Support for abstraction		•	•
Expressivity		•	•
Type checking			•
Exception handling			•
Restricted aliasing			•

Cost is not included in the table because it is only slightly related to the other criteria and the characteristics that influence them.

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Language Evaluation Criteria

- Readability
  - *The ease with which programs can be read and understood*
    - e.g. by someone else (or the programmer at a later time)
- Writability
  - *The ease with which a language can be used to create programs*
    - e.g. power of constructs vs clarity of constructs
- Reliability
  - *Conformance to specifications (i.e., performs to its specifications) in ALL situations – particularly as it applies to a software developer. Does the language help a programmer to write correct programs?*

Language Evaluation Criteria

- Cost
  - *The ultimate criterion*
    - not just the cost of the initial development
  - *The truth is that it always comes down to money.*
  - *But remember - cheapest in the short-term is not always cheapest over the life of a software artifact.*

Readability

- Overall simplicity
  - *A manageable set of features and constructs*
  - *Few feature multiplicity (means of doing the same operation)*
  - *Minimal operator overloading*
- Orthogonality
  - *A relatively small set of primitive constructs can be combined in a relatively small number of ways*
  - *Purely Orthogonal - Every possible combination is legal*
  - *No language will be purely orthogonal – all will have a level of orthogonality*

Readability

- Control statements
  - *The presence of well-known control structures*
    - e.g., `while` statement, `if-then-else` statement
- Data types and structures
  - *The presence of adequate facilities for defining data structures*
    - Or more generally – abstraction and modularization
- Syntax considerations
  - *Identifier forms: flexible composition*
  - *Special words and methods of forming compound statements*
  - *Form and meaning: self-descriptive constructs, meaningful keywords*

Writability

- Simplicity and orthogonality
  - *Few constructs, a small number of primitives, a small set of rules for combining them*
- Support for abstraction
  - *The ability to define and use complex structures or operations in ways that allow details to be ignored*
- Expressivity
  - *A set of relatively convenient ways of specifying operations*
    - Example: What's wrong with the `while` statement?
    - Example: the inclusion of `for` statement in many modern languages

Reliability

- Type checking
  - *Testing for type errors*
- Exception handling
  - *Intercept run-time errors and take corrective measures*
- Aliasing
  - *Presence of two or more distinct referencing methods for the same memory location*
- Readability and Writability
  - *A language that does not support "natural" ways of expressing an algorithm will necessarily use "unnatural" approaches, and hence reduced reliability*

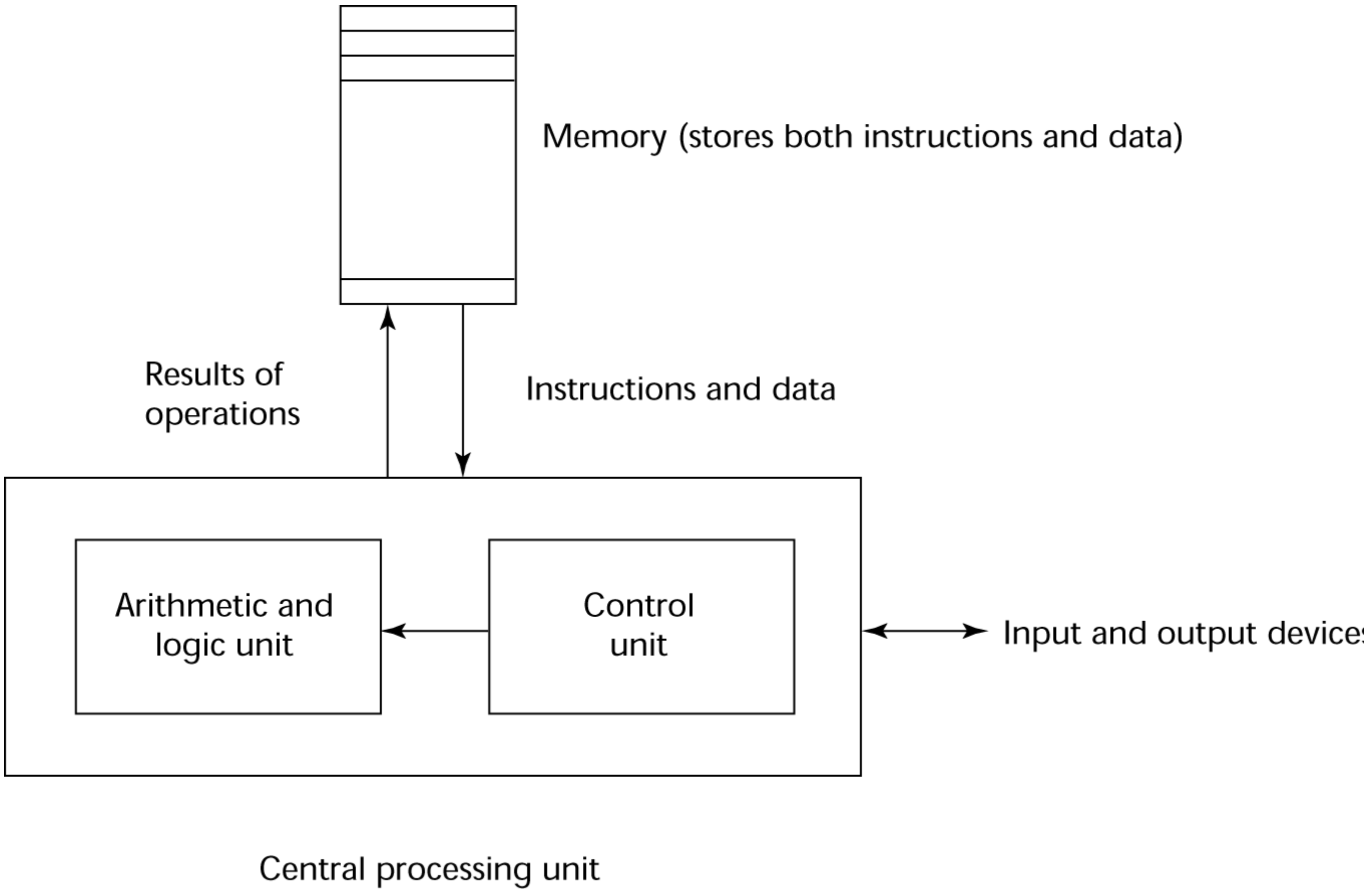
Cost

- Training programmers to use the language
- Writing programs (closeness to particular applications)
- Compiling programs
- Executing programs
- Language implementation system: availability of free compilers
- Reliability: poor reliability leads to high costs
- Maintaining programs
  - *This does not just refer to fixing errors*
  - *Extending a program and integrating it with/into another system is part of maintenance (and often the most important part)*

Influences on Language Design

- Computer Architecture
  - *Languages are developed around the prevalent computer architecture, known as the von Neumann architecture*
- Programming Methodologies
  - *New software development methodologies (e.g., object-oriented software development) led to new programming paradigms and by extension, new programming languages*

Computer Architecture



Von Neumann Architecture

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Computer Architecture

Imperative languages, most dominant, because of von Neumann computers

- Data and programs stored in memory
- Memory is separate from CPU
- Instructions and data are piped from memory to CPU
- Basis for imperative languages
  - *Variables model memory cells*
  - *Assignment statements model piping*
  - *Iteration is efficient*

Programming Methodology

- 1950s and early 1960s: Simple applications; worry about machine efficiency
- Late 1960s: People efficiency became important; readability, better control structures
  - *structured programming*
  - *top-down design and step-wise refinement*
- Late 1970s: Procedure-oriented to data-oriented
  - *data abstraction*
- Middle 1980s: Object-oriented programming
  - *Data abstraction + inheritance + polymorphism*

Language Categories

- Imperative
  - *Central features are variables, assignment statements, and iteration*
  - *Examples: C, Pascal*
- Functional
  - *Main means of making computations is by applying functions to given parameters*
  - *Examples: LISP, Scheme*
- Logic
  - *Rule-based (rules are specified in no particular order)*
  - *Example: Prolog*

Language Categories

- Object-oriented
  - *Encapsulation and Information Hiding*
    - Data abstraction
  - *Inheritance*
    - Re-use
  - *Polymorphism (late binding)*
    - Extensibility
  - *Examples: Java, C++, C#, Eiffel, Smalltalk*
- Markup
  - *New; not a programming category per se, but used to specify the layout of information in Web documents*
  - *Examples: XHTML, XML*

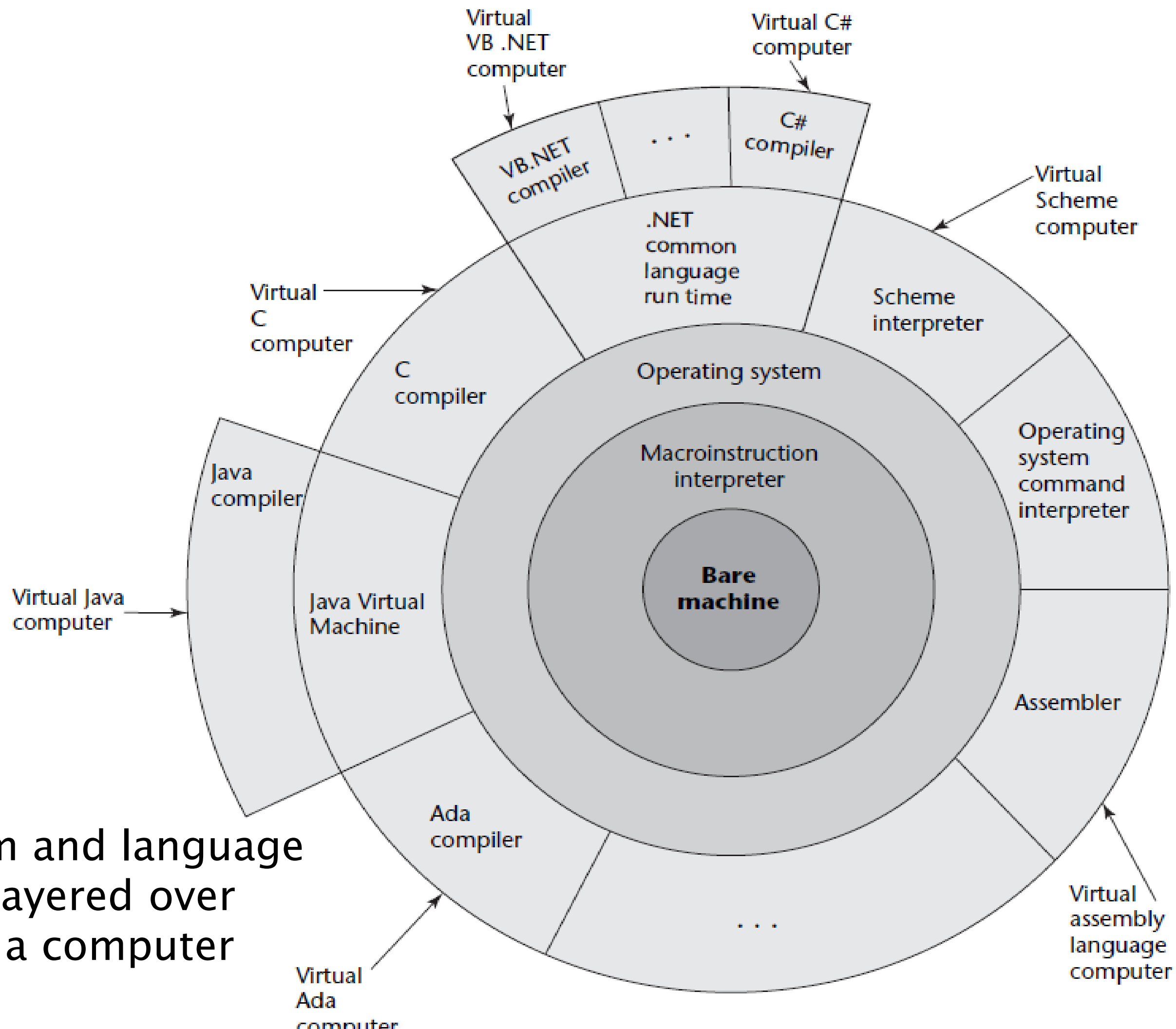
Language Design Trade-Offs

- Reliability vs. cost of execution
  - *Conflicting criteria*
  - *Example: Java demands all references to array elements be checked for proper indexing but that leads to increased execution costs*
- Readability vs. writability
  - *Another conflicting criteria*
  - *Example: APL provides many powerful operators (and a large number of new symbols), allowing complex computations to be written in a compact program but at the cost of poor readability*
- Writability (flexibility) vs. reliability
  - *Another conflicting criteria*
  - *Example: C++ pointers are powerful and very flexible but not reliably used*

Implementation Methods

- Compilation
  - *Programs are translated into machine language*
- Pure Interpretation
  - *Programs are interpreted by another program known as an interpreter*
- Hybrid Implementation Systems
  - *A compromise between compilers and pure interpreters*

Layered View of Computer



The operating system and language implementation are layered over Machine interface of a computer

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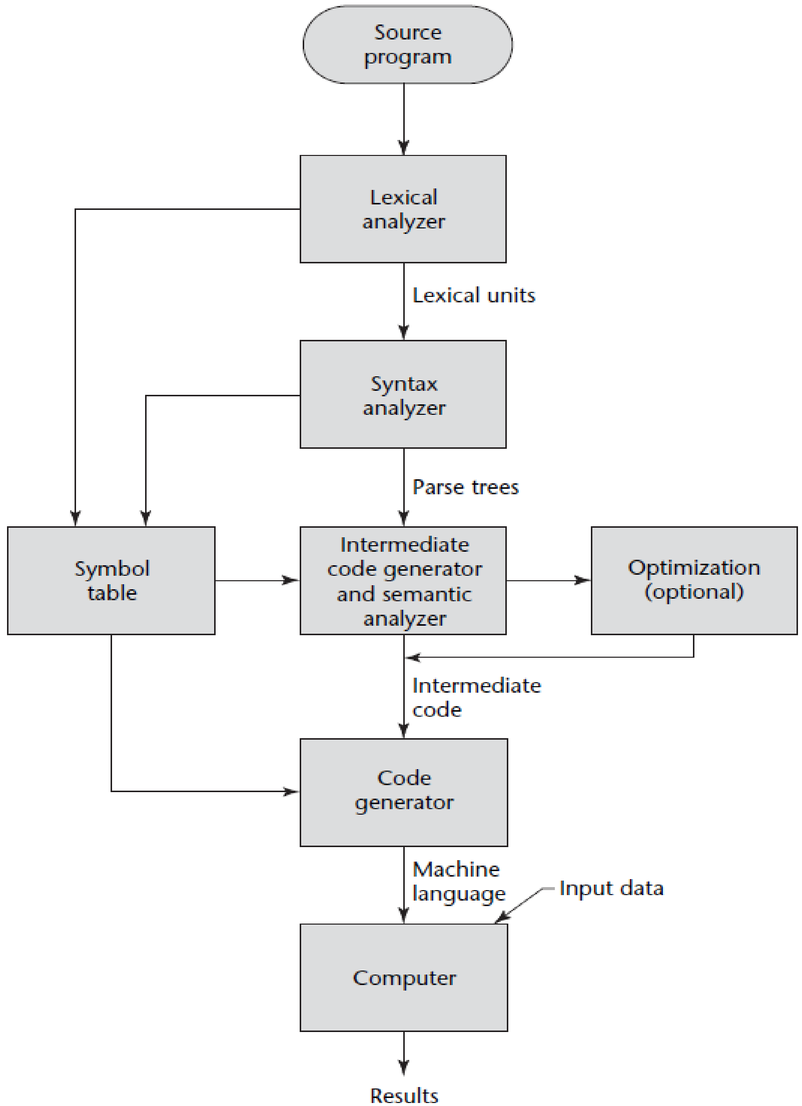
Compilation

- Translate high-level program (source language) into machine code (machine language)
- Slow translation, fast execution
- Compilation process has several phases:
  - *lexical analysis: converts characters in the source program into lexical units*
  - *syntax analysis: transforms lexical units into parse trees which represent the syntactic structure of program*
  - *Semantics analysis: generate intermediate code*
  - *code generation: machine code is generated*

Compilation Process



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Additional Compilation Terms

- Load module (executable image): the user and system code together
- Linking and loading: the process of collecting system program and linking them to user program

Execution of Machine Code

Fetch-execute-cycle (on a von Neumann architecture)

```
initialize the program counter
repeat forever
    fetch the instruction pointed by the counter
    increment the counter
    decode the instruction
    execute the instruction
end repeat
```

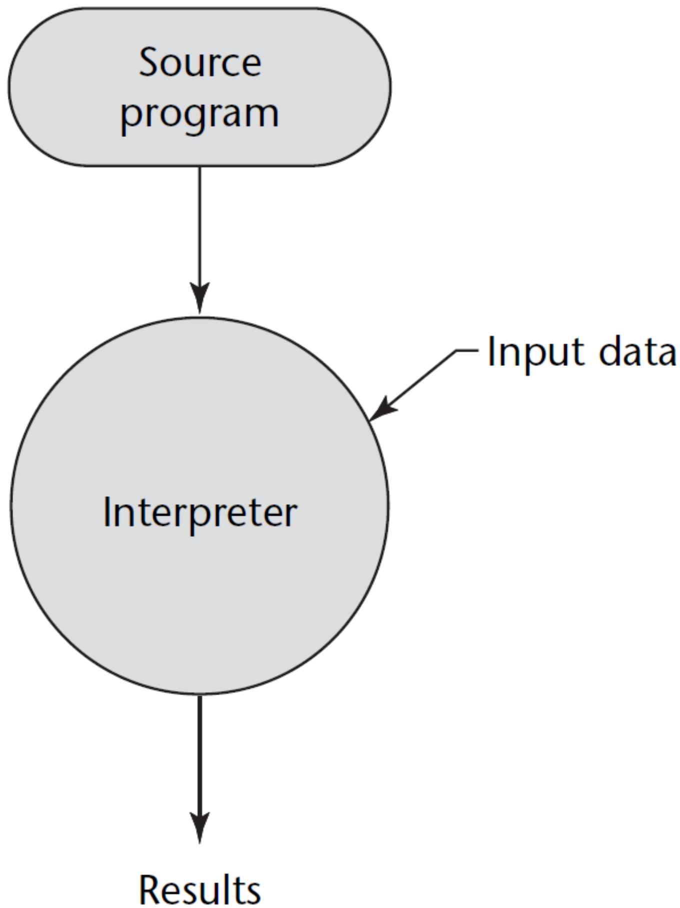
Von Neumann Bottleneck

- Connection speed between a computer's memory and its processor determines the speed of a computer
- Program instructions often can be executed a lot faster than the above connection speed; the connection speed thus results in a bottleneck
- Known as von Neumann bottleneck; it is the primary limiting factor in the speed of computers

Pure Interpretation

- No translation
- Easier implementation of programs (run-time errors can easily and immediately displayed)
- Slower execution (10 to 100 times slower than compiled programs)
- Often requires more space
- Becoming rare on high-level languages
- Significant comeback with some Web scripting languages (e.g., JavaScript)

Pure Interpretation Process



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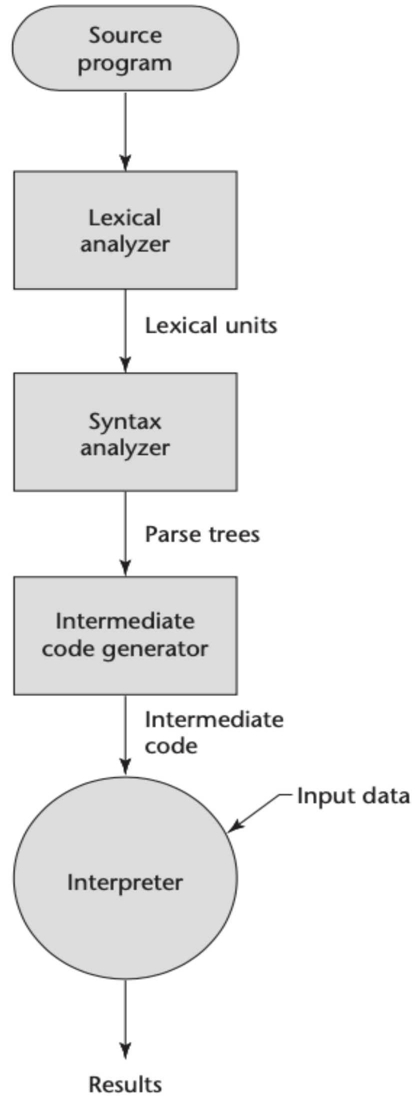
Hybrid Implementation Systems

- A compromise between compilers and pure interpreters
- A high-level language program is translated to an intermediate language that allows easy interpretation
- Faster than pure interpretation
- Examples
  - *Perl programs are partially compiled to detect errors before interpretation*
  - *Initial implementations of Java were hybrid; the intermediate form, byte code, provides portability to any machine that has a byte code interpreter and a run-time system (together, these are called Java Virtual Machine)*

Hybrid Implementation Systems



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Just-in-Time (JIT) Implementation Systems

- Initially translate programs to an intermediate language
- Then compile intermediate language into machine code
- Machine code version is kept for subsequent calls
- JIT systems are widely used for Java programs
- .NET languages are implemented with a JIT system
- JIT is also used in some research languages in attempting to implement “live activation” of updated features.

Preprocessors

- Preprocessor macros (instructions) are commonly used to specify that code from another file is to be included
- A preprocessor processes a program immediately before the program is compiled to expand embedded preprocessor macros
- A well-known example: C preprocessor
    - *expands #include, #define, and similar macros*

Programming Environments

- The collection of tools used in software development
- UNIX
  - *An older operating system and tool collection*
  - *Nowadays often used through a GUI (e.g., CDE, KDE, or GNOME) that run on top of UNIX*
- IntelliJ IDEA
  - *An integrated development environment for Java*
- Microsoft Visual Studio.NET
  - *A large, complex visual environment*
  - *Used to program in C#, Visual BASIC.NET, Jscript, J#, or C++*

Summary of Part 2

- The study of programming languages is valuable for a number of reasons:
  - *Increase our capacity to use different constructs*
  - *Enable us to choose languages more intelligently*
  - *Makes learning new languages easier*
- Most important criteria for evaluating programming languages include:
  - *Readability, writability, reliability, cost*
- Major influences on language design have been machine architecture and software development methodologies
- The major methods of implementing programming languages are: compilation, pure interpretation, and hybrid implementation

Part 3 - UML

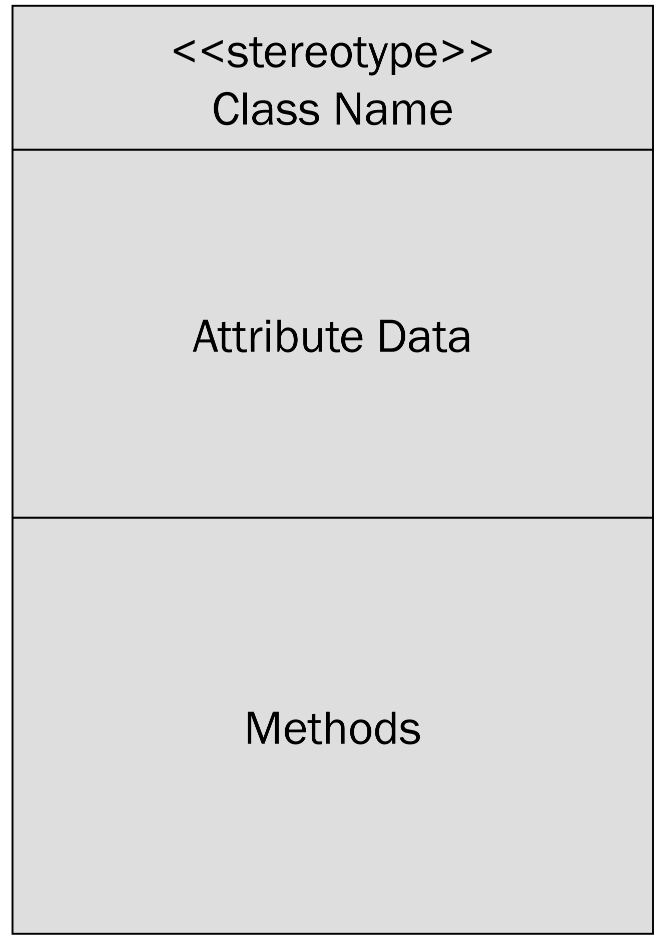
UML

- As we compare implementations of various abstractions and algorithms, Unified Modeling Language (UML) will be the means of presenting the designs being implemented.
- Class Specifications
- Class Diagrams
- Class Interactions

- We will not need:
  - *Use-cases*
  - *Sequence Diagrams*
  - *Etc.*

UML Class Specification

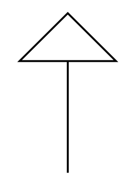
- Each class has a name, and the stereotype is optional
- A set of data items or attributes
- A set of methods
- + - and # indicate public, private or protected items
- Public methods constitute the interface of the class



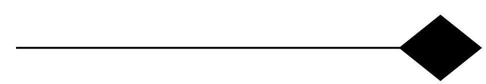
Relationship

- **Association** - may have been used in examples for data structures

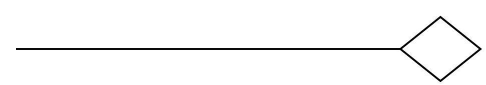
- **Inheritance** - you may not have seen this, there is also a version for implementation of an interface



- **Composition** – strong lifecycle dependency



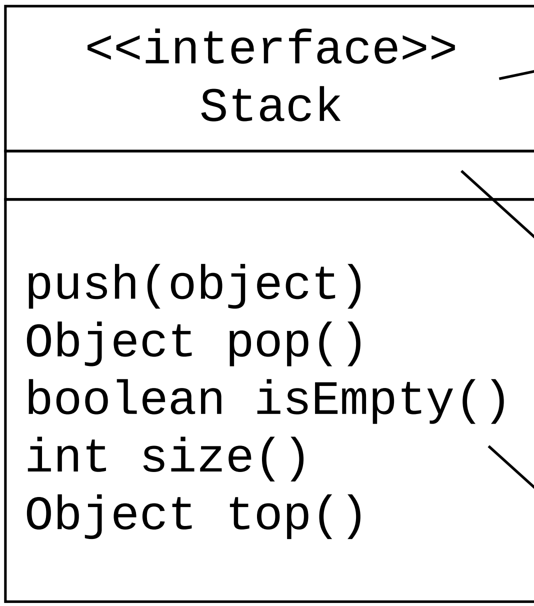
- **Aggregation** – "part of"



Examples

- Interface
- Class
- Realization
- Class Diagram

Interface - “Stack”



<<interface>> is a UML “stereotype”

An interface has no attributes (data)

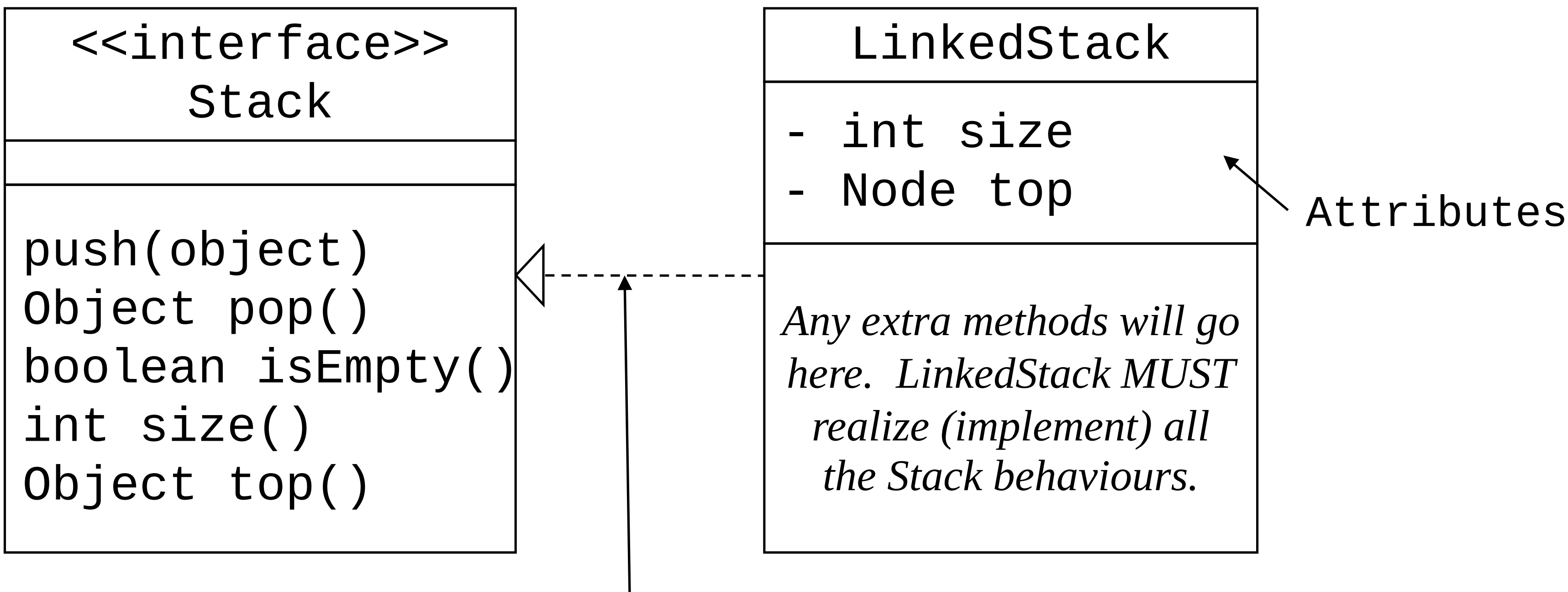
An interface lists a set of behaviours (effectively - specification of messages)

UML for Class “Node”

- Note that the Node Class has a Node attribute (a reference) as a link to the next element in the list.
- It also has a reference of type Object to hold the object itself.
- The Node Class becomes part of a set of classes and interfaces that will become the linked list.

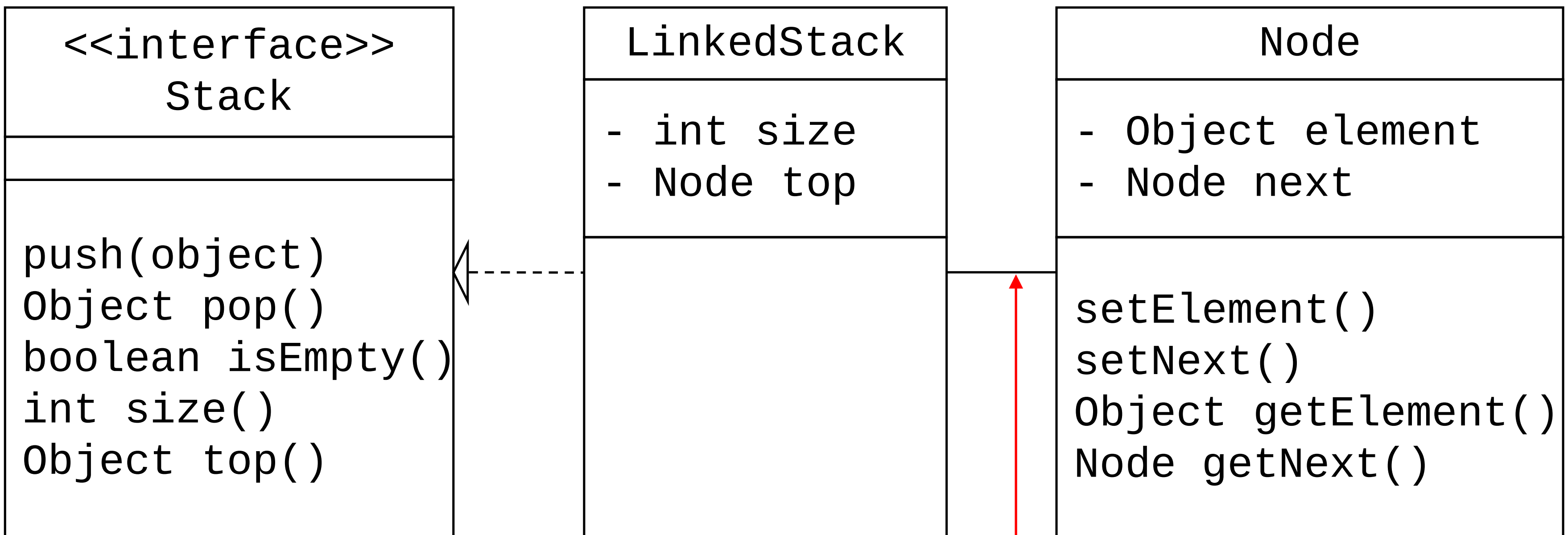
Node
- Object element - Node next
setElement() setNext() Object getElement() Node getNext()

Realization



- LinkedStack is a realization of interface Stack
- – the UML term is implementation (implements)
- – following the Java keyword which is also *implements*

Class Diagram



The ——— relationship between classes can also show direction and number.
E.g 1 0…*

Indicates that Class LinkedStack **uses** or refers to Class Node.