CSC9Y4 Programming Language Paradigms

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Course aims

Two main aims:

- Broaden your view of programming languages. Java is not the *only* way.
- Give an understanding of the general principles common to all programming languages.

Side effect:

- improve your understanding of Java by seeing ***why*** things are done in a certain way.

Course aims

Hundreds of different programming languages exist.

There are different ***kinds/families*** of language (paradigms).

Programming in a ***logic language***, for example, is very different from programming in Java.

BUT the similarities still outweigh the differences.

Once you know how to program in one language, it is straightforward to learn other related languages.

The emphasis in the course is on showing the similarity and the connection between apparently dissimilar language features.

Organisation

Schedule: see online

Lecture attendance - a good idea!

Textbook (essential reading): *Comparative Programming Languages* (3rd ed.), R.G.Clark, Publisher: Addison-Wesley

Software Development Process

Programming languages used as part of the software life cycle.

We have the following phases:

- requirements capture,
- problem specification,
- design,
- implementation,
- validation and verification,
- maintenance.

Software Development Process

Different life cycle models, e.g. waterfall model and spiral model.

Note that:

- Phases of the software life-cycle are not independent
- The process is iterative
- Knowledge of the implementation language influences the design

The design of modern programming languages has been greatly influenced by the needs of the software development process.

Language Design

The primary purpose of a programming language is to support the construction of ***reliable software***.

How can the ***design of a language*** support software reliability?

Expressive power

Allow solutions to be expressed in terms of the problem being solved rather than in terms of computer instructions.

Language Design

Orthogonality

Small number of basic constructs which can be combined systematically to give more complex structures.

Few, if any, special cases.

Pragmatic considerations?

Law of Minimum Surprise

Language Design

Error Detection and Correction

Testing.

Errors should be shown up at ***compile time***. Why?

Language design example: require the type of all variables to be declared. How will this help?

This leads to the notion of

strong typing

- all expressions have a well defined type.

static typing

- the type of all variables is fixed at compile time.

- Hence ***static strong typing*** is where the types of all variables are well defined at compile time.

Fortran Example

Consider the following two statements:

```
DO 20 I = 1,30
DO 20 I = 1.30
```

When a simple typing error is made, it should result in a syntax error, not in a statement with a different meaning.

An American space probe missed the moon due to the above error. Resulted in them giving up Fortran.

Language Design

Correctness

Not just testing to show it works - *prove* it works.
More common with ***declarative languages***.

Language Design

Standards

- **ISO** and **ANSI**
- Standard definitions give the ***syntax*** (structure) and ***semantics*** (meaning) of each language construct.
- Problem of ***dialects*** (subsets or supersets).

Language Design

Size

Small and (Beautiful? Constrained? Simple?)

Large and (Multipurpose? Bloated? Too Complex?)

Some successful languages were explicitly designed to be small:

Pascal much smaller than Algol 68; Java removed many features from C++.

Is Java large or small?

Language Design

Language Implementation

Imperative programs (e.g. in Pascal, Ada, C, C++) are usually ***translated*** (***compiled***) into an equivalent ***machine code*** program which is then executed.

Does this translation affect the acceptability of a language?

Examples: PL/I, Algol 68, Ada, Pascal, Delphi.

Language Design

Language Implementation (continued)

Or, use an ***interpreter***.

An interpreter can directly execute a ***source program.***

Or (nowadays)

source program⇒program in a ***virtual machine language***

And the interpreter executes the virtual machine language.

Language Design

Language Implementation (continued)

Java is interpreted for portability reasons.

Browsers such as Netscape and Internet Explorer include implementations of the Java virtual machine (JVM).

Otherwise Java has the features of a conventional compiled imperative language.

Brief history of languages

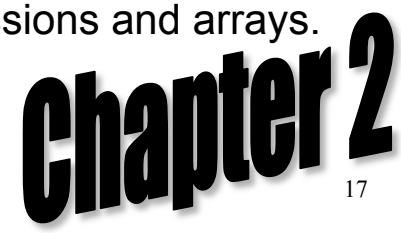
Early machines were very small (1K store, no decent peripherals).

Binary code.

Next step: a symbolic form of machine code (assembly language)

```
LDA 0
BNE LABEL
```

Autocodes developed adding expressions and arrays.



Imperative Languages

Observation:

- Computers have individually addressable store locations which can contain instructions or data.
- Machine code programs achieve their effect by changing the contents of store locations.

- There is a lose connection between machine code and imperative languages
  - This means efficient implementations.

Imperative Languages

Recall von Neumann architecture: an addressable store, programs as data, fetch-execute cycle.

How does this relate to Imperative languages?

A variable or object corresponds to one or more store locations.

Programs achieve their effect by changing the values of variables or objects.

Instructions are executed in sequence with jump instructions altering the flow.

Fortran

first manual released: 1956; first full implementation: 1958

successful beyond the expections of its inventors, and influenced all later imperative languages.

aimed at scientific computation

allowed programmers to express solutions in mathematical notation

major selling point: machine independence

A Fortran program consists of a main program,

subroutines (like procedures) and functions.

Still widely used; latest version is Fortran 90.

Algol 60

The next major procedural language was Algol 60, designed during 1958-1963.

- The original block-structured language
- Used recursion

Its syntax was defined formally using Backus Naur Form (BNF).

Algol 60 did not replace Fortran, but languages such as Pascal are its direct descendents.

BNF is still the normal way in which the syntax of programming languages is defined.

Later imperative languages

Cobol

Universal languages?

- PL/I was a large language developed by IBM in the mid-sixties.
- Algol 68 was designed as the replacement for Algol 60, but was large, too complex and was never in widespread use.

Smaller languages?

- Pascal was developed around 1970. It cleaned up and extended Algol 60.
- C also developed at that time and took features from Algol and Fortran. Main use was as an efficient systems programming language. It eventually killed off assemblers.

Language Categories

Two kinds of imperative language: ***procedural*** and ***object-oriented***.

Until late 1990s, procedural languages were dominant.

Many procedural languages now have new versions that are object-oriented:

C++ from C, Delphi from Pascal, Ada 95 from Ada 83, Object Cobol from Cobol.

Hybrid rather than pure OO languages.

Modules

Modula 2, Modula 3 and Ada developed from Pascal in late 70s and early 80s.

Their main addition is the ***module***.

Ada developed by *US Department of Defense* to be the standard language used on ***all*** defence contracts.

Modules

Emphasis shift from algorithms to data structures.

Many good features:

- ***Encapsulation***
- ***Information hiding***
- ***Data abstraction***
- ***Decomposition***
- ***Localising changes***
- ***Component re-use***

Modules

In Ada, the module construct is called a package.

Packages can be used to group together the definition of a type and its associated operations.

In C++ and Java, the module is a class; it defines a new type.

Similar but different:

Packages are primarily a program structuring device while classes define a type.

Object-oriented languages

First OO language was Simula 67.

Developed from Algol 60 with the addition of classes.

Defined as a simulation language, but found to be a useful systems language.

Smalltalk developed in 1970s. Its development environment introduced concepts of window, mouse, menu and icon, i.e. the GUI.

Weakly typed and can be used to rapidly implement prototypes. In Smalltalk, everything is an object.

Object-oriented languages

C++ developed in 1980s, by adding classes to C. Hybrid language.

Eiffel developed from Pascal in late 1980s to introduce good software engineering principles to OO programming.

Delphi is an OO extension of Pascal.

Java intoduced in mid 1990s as a simplification of C++.

C# developed as Microsoft's answer to Java.

Declarative languages

Functional and logic languages are ***declarative languages***.

Declarative languages concentrate on stating ***what*** is to be done rather than on ***how*** it is to be done.

Pro:

- shorter and more reliable programs
- easier to reason about programs (provably correct programs)

Con:

- less efficient

Overview

The course examines different kinds of programming language:

- **Object-oriented languages**, e.g. Java, Smalltalk;
- **Procedural languages**, e.g. Pascal, C, Fortran, Cobol;
- **Logic languages**, e.g. Prolog;
- **Functional languages**, e.g. ML;
- **Scripting Languages**, e.g. Perl, Javascript, PHP

C++ and Ada 95 can be considered to be hybrid object-oriented/procedural languages.