Introduction to Computer Science
Lecture 6: Programming Languages

Tian-Li Yu

Taiwan Evolutionary Intelligence Laboratory (TEIL)
Department of Electrical Engineering
National Taiwan University
tianliyu@cc.ee.ntu.edu.tw

Slides made by Tian-Li Yu, Jie-Wei Wu, and Chu-Yu Hsu

PL Generations

1st	2nd	3rd	4th	⟶
Machine Instructions	Assembly (Mnemonic system of MIs)	Fortran Cobol Basic C/C++ Java	SQL SAS	

Assembler: Translating MIs to Assembly

- 1^{st}
  Machine instructions
- 2^{nd}
  Assembly

156C	$\longrightarrow$	LD R5, Price
166D	$\longrightarrow$	LD R6, ShippingCharge
5056	$\longrightarrow$	ADDI R0, R5, R6
306E	$\longrightarrow$	ST R0, TotalCost
C000	$\longrightarrow$	HTL

- Mnemonic names for op-codes
- Identifiers: Descriptive names for memory locations, chosen by the programmer

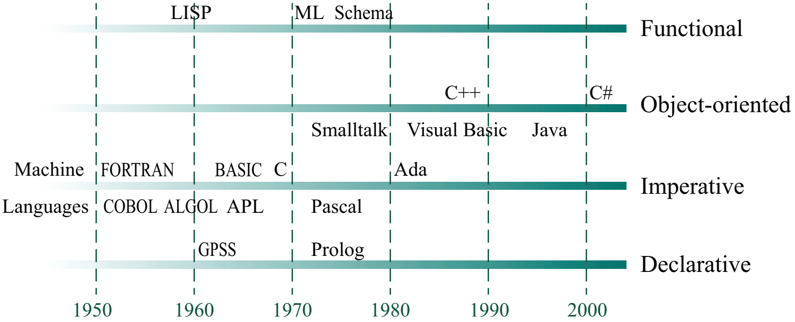
3^{rd} Generation Languages (3GL)

- Characteristics of assembly
  - Machine dependent
  - One-to-one mapping
  - Assembler
- High-level primitives
- Machines independent (virtually)
- One primitive to many MI mapping
- Compiler & interpreter

Languages and Issues

- Natural vs. formal languages
  - Formal language → formal grammar
- Portability
  - Theoretically: different compilers
  - Reality: Minor modifications

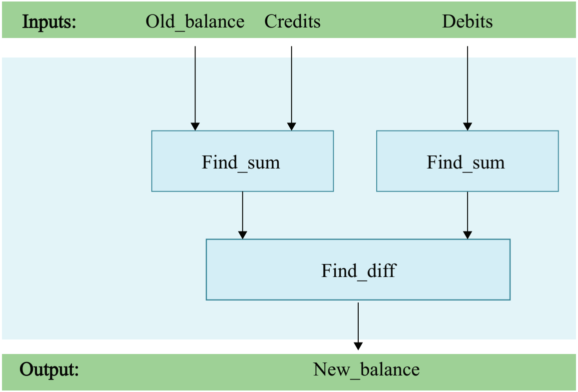
Programming Paradigms



Imperative vs. Declarative

- Imperative paradigm
  - Procedural
  - Approaching a problem by finding an algorithm to solve the problem.
- Declarative paradigm
  - Implemented a general problem solver
  - Approaching a problem by finding a formal description of the problem.
  - Will talk more about this later.

Functional Paradigm



Functional vs. Imperative

(Find_diff (Find_sum Old_balance Credits) (Find_sum Debits))

Temp_balance ← Old_balance + Credit
Total_debits ← sum of all Debits
Balance ← Temp_balance – Total_debits

(Find_Quotiant (Find_sum Numbers) (Find_count Numbers))

Sum ← sum of all Numbers
Count ← # of Numbers
Quotiant ← Sum / Count

Object-Oriented Paradigm

- OOP (object-oriented programming)
- Abstraction
- Information hiding
  - Encapsulation
  - Polymorphism
- Inheritance

- References:
  - http://www.codeproject.com/KB/architecture/OOP_Concepts_and_manymore.aspx
  - http://en.wikipedia.org/wiki/Object-oriented_programming

More about Imperative Paradigm

- Variables and data types
- Data structure
- Constants and literals
- Assignment and operators
- Control
- Comments

Variables and Data Types

- Integer
- Real (floating-point)
- Character
- Boolean

FORTRAN

```
INTEGER  a, b
REAL     c, d
BYTE     e, f
LOGICAL  g, h
```

Pascal

```
a, b:  integer;
c, d:  real;
e, f:  char;
g, h:  boolean;
```

C/C++ (Java)

```
int  a, b;
float c, d;
char e, f;
bool g, h;
```

Data Structure

- Homogeneous array
- Heterogeneous array

FORTRAN `INTEGER a(6,3)`

Pascal `a: array[0..5,0..2] of integer;`

C/C++ `int a[5][2];`

C/C++

```
struct{
    char  Name[25];
    int  Age;
    float  SkillRating;
} Employee;
```

Constant and Literals

- a ← b + 645;
  - 645 is a literal
- const int a=645;
- final int a=645;
- A constant cannot be a l-value.
  - a=b+c;

Assignment and Operators

APL

```
a <- b + c;
```

Ada, Pascal

```
a := b + c;
```

C/C++ (Java)

```
a = b + c;
```

- Operator precedence
- Operator overloading

Control

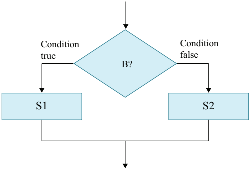
- Old-fashion: goto

```
       goto 40
20     print "passed."
       goto 70
40     if (grade < 60) goto 60
       goto 20
60     print "failed."
70     stop
```

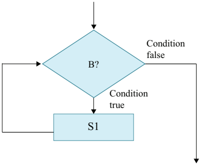
- Not recommended in modern programming
  - Modern programming

```
if (grade < 60)
     then print "failed."
     else print "passed."
```

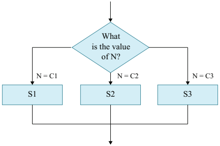
Control Structures




```
if (B) S1
  else S2;
```

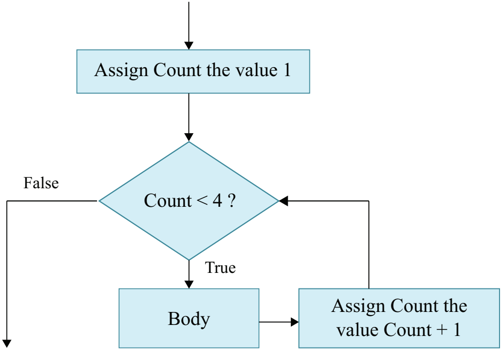



```
while (B)
  S1;
```




```
switch  (N)
{ case C1:  S1;break;
   case C2:  S2;break;
   case C3:  S3;break;
};
```

Control Structures (contd.)




```
for (int Count = 1; Count < 4; Count++)
     body;
```

Comments

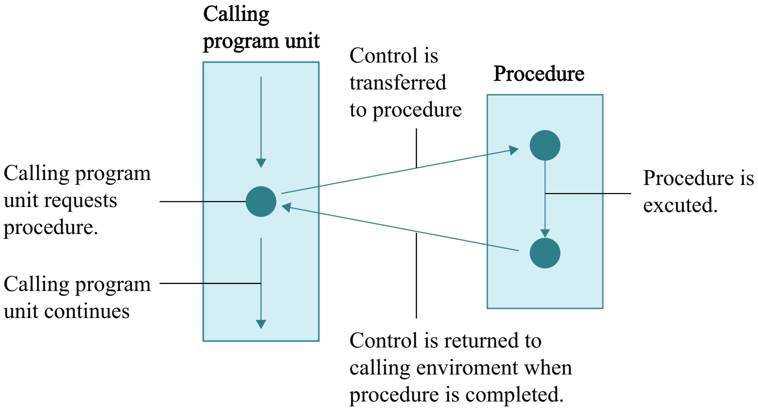
- C/C++, Java

```
a = b + c; // This is an end-of-line comment
```

```
/*
    This is a
    block comment
*/
a = b + c;
```

```
/**
    This is a
    documentation
    comment
*/
a = b + c;
```

Calling Procedures



Terminology

Starting the head with the term “void” is the way that a C programmer specifies that the program unit is a procedure rather than a function. We will learn about functions shortly.

The former parameter list. Note that C, as with many programming languages, requires that the data type of each parameter be specified.

```
void  ProjectPopulation  (float GrowthRate){

int Year;

Population[0] = 100.0;
for (Year = 0; Year =< 10; Year++)
  Population[Year+1] = Population[Year] + (Population[Year]*GrowthRate);

}
```

This declares a local variable named Year.

These statements describe how the populations are to be computed and stored in the global array named Population.

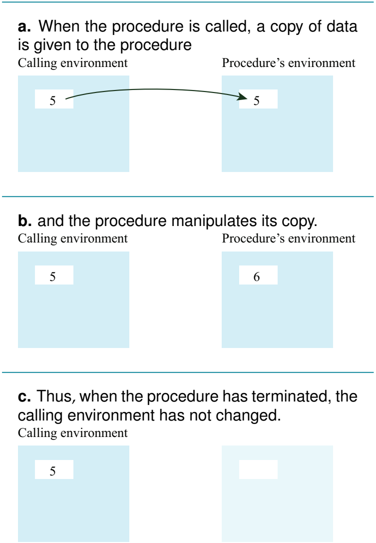
Terminology (contd.)

- Procedure's header
- Local vs. global variables
- Formal vs. actual parameters
- Passing parameters
  - Call by value (passed by value)
  - Call by reference (passed by reference)
  - Call by address: variant of call-by-reference.

Call by Value

procedure Demo(*Formal*)
Formal ← *Formal* + 1;

Demo(*Actual*);



Call by Reference

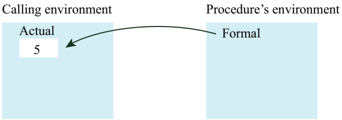
procedure Demo(*Formal*)
Formal ← *Formal* + 1;

Demo(*Actual*);

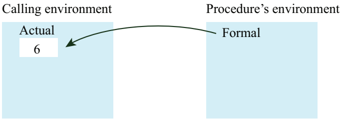
C/C++

```
void Demo(int& Formal){
    Formal = Formal + 1;
}
```

a. When the procedure is called, the formal parameter becomes a reference to the actual parameter.



b. Thus, changes directed by the procedure are made to the actual parameter



c. and are, therefore, preserved after the procedure has terminated.

Functions vs. Procedures

- A program unit similar to a procedure unit except that a value is transferred back to the calling program unit as “the value of the function.”

The function header begins with the type of the data that will be returned.

```
float CylinderVolumn  (float Radius, float Height){
float Volume;
Volume = 3.14 * Radius * Radius * Height;
return Volume;
}
```

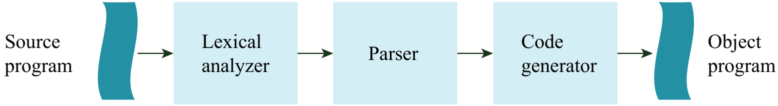
Terminate the function and return the value of the variable Volume

Compute the volume of the cylinder

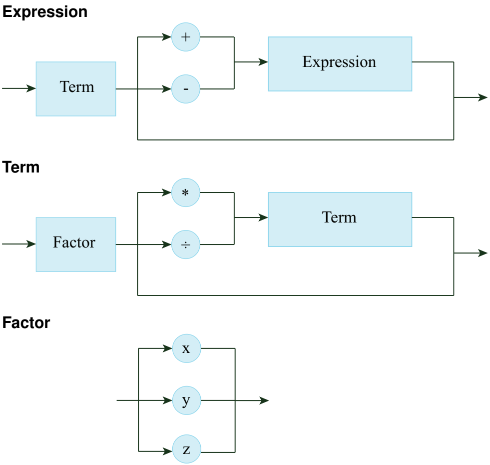
This declares a local variable named Volume.

The Translation Process

- Lexical analyzer: identifying tokens.
- Parser: identifying syntax & semantics.



Syntax Diagrams for Algebra



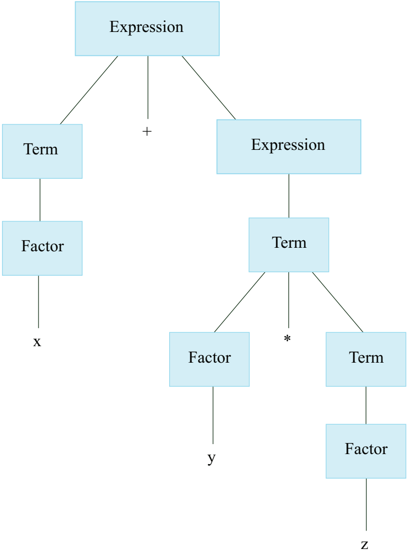
Grammar for Algebra

- Expression $\rightarrow$ Term | Term **+** Expression
  | Term **-** Expression
  Term $\rightarrow$ Factor | Factor $*$ Term | Factor / Term
  Factor $\rightarrow$ **x** | **y** | **z**

- Starting: Expression
- Nonterminals: Expression, Term, Factor
- Terminals: **+**, **-**, *, /, **x**, **y**, **z**

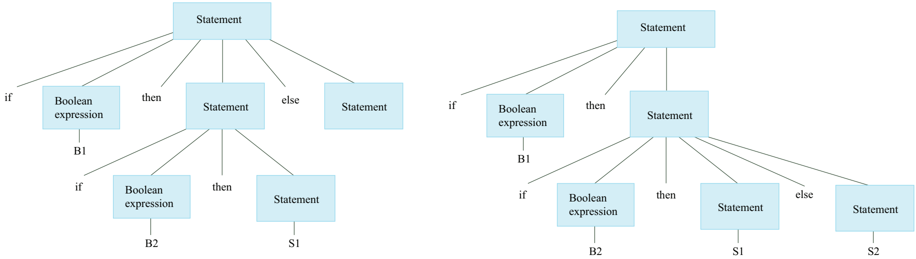
Parse Tree

- $x + y * z$



Ambiguity

- **if** B1 **then if** B2 **then** S1 **else** S2



Code Generation

- Coercion: implicit conversion between data types
- Strongly typed: no coercion, data types have to agree with each other.
- Code optimization
  - x = y + z;
  - w = x + z;

  - w = y + (z << 1);

OOP

- Object
  - Active program unit containing both data and procedures
- Class
  - A template from which objects are constructed
  - An object is an instance of the class.

- Instance variables & methods (member functions)
- Constructors
  - Special method used to initialize a new object when it is first constructed.
- Destructors vs. garbage collection

An Example of Class

Constructor assigns a value to Remaining Power when an object is created.

Instance variable

```
class LaserClass
{ int RemainingPower;

  LaserClass (InitialPower)
  { RemainingPower = InitialPower;
  }

  void turnRight ( )
  { ... }

  void turnLeft ( )
  { ... }

  void fire ( )
  { ... }

}
```

methods

Encapsulation

- Encapsulation
  - A way of restricting access to the internal components of an object
  - Bundling of data with the methods operating on that data.
- Examples: private vs. public, getter & setter

Polymorphism

- Polymorphism
  - Allows method calls to be interpreted by the object that receives the call.
  - Allows different data types to be handled using a uniform interface.

```
Circle();
Rectangle();
```

```
Circle circle;
Rectangle rect;

circle.draw();
rect.draw();
```

Inheritance

- Inheritance
  - Allows new classes to be defined in terms of previously defined classes.

```
Class Base;
Class Circle : Base;
Class Rectangle : Base;
```

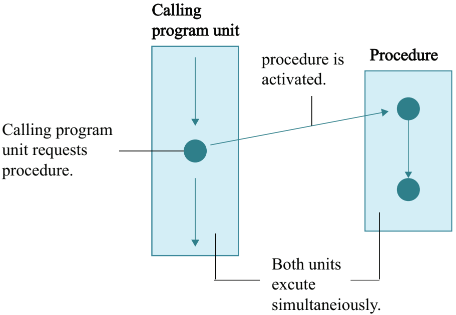
```
Base *base;
Circle circle;
Rectangle rect;

base = & circle;
base -> draw();
base = & rect;
base -> draw();
```

Concurrency

Mutual Exclusion: A method for ensuring that data can be accessed by only one process at a time.

Monitor: A data item augmented with the ability to control access to itself

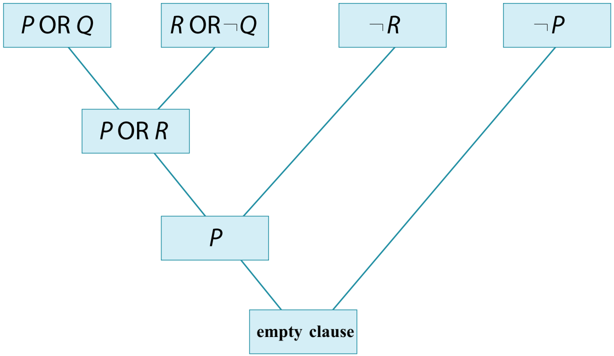


Declarative Programming

- **Resolution**
  - Combining two or more statements to produce a new statement (that is a logical consequence of the originals).
  - $(P \text{ OR } Q)$ AND $(R \text{ OR } \neg Q)$ resolves to $(P \text{ OR } R)$
  - **Resolvent**: A new statement deduced by resolution
  - **Clause form**: A statement whose elementary components are connected by `OR`
- **Unification**
  - Assigning a value to a variable so that two clauses would be the same.
  - `Unify(Father(Mark,John), Father(x,John))` results in `x is Mark`.

Proof by Resolution (Refutation)

- We know that (P OR Q) AND (R OR $\neg Q$) AND ($\neg R$) is true (KB, knowledge base).
- We want to prove that P is true.
- Prove by showing that KB AND $\neg P$ is unsatisfiable (empty clause).



Prolog

- **Variables:** first letter capitalized (exactly contrary to common logics).
- **Constants:** first letter uncapitalized.
- **Facts:**
  - Consists of a single predicate
  - *predicateName*(*arguments*).
    - `parent(bill, mary).`
- **Rules:**
  - conclusion :- premise.
    - `:-` means "if"
  - `faster(X,Z) :- faster(X,Y), faster(Y,Z).`

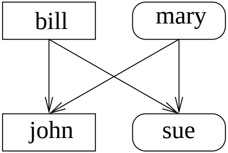
- = (unification: term=term)
  - $1 + X = Y + 2 \quad \rightarrow \quad X = 2$ and $Y = 1$
  - $X = 1 + 3 \quad \rightarrow \quad X = 1 + 3$
  - $2 + 2 = 1 + 3 \quad \rightarrow \quad no$
- is (assignment: term is evaluable)
  - X is $1 + 3 \quad \rightarrow \quad X = 4$
  - $1 + X$ is $4 \quad \rightarrow \quad no$
- == (text comparison: term == term)
  - $X == 1 + 3 \quad \rightarrow \quad no$
  - $1 + X == 1 + X \quad \rightarrow \quad yes$
  - $2 + 2 == 1 + 3 \quad \rightarrow \quad no$
- =:= (comparison: evaluable =:= evaluable)
  - $2 + 2 =:= 1 + 3 \quad \rightarrow \quad yes$
- **Other operators:**

  \=, =\=, <, >, +, -, *, /, >=, =<

Gnu Prolog

- Gnu prolog `http://www.gprolog.org/`
- Interactive mode
  - Under the prompt `| ?-` , type `[user].`
  - When finished, type `Ctrl-D`
- Comments
  - /* */ or %
- Chinese incompatible.
- You may consult *.pl (a pure text file)

Prolog Examples




```
female(mary).
female(sue).
male(bill).
male(john).

parent(mary,john).
parent(bill,john).
parent(mary,sue).
parent(bill,sue).


mother(X,Y):-female(X),parent(X,Y).
father(X,Y):-male(X),parent(X,Y).

son(X,Y):-male(X),parent(Y,X).
daughter(X,Y):-female(X),parent(Y,X).

sibling(X,Y):-X\=Y,parent(Z,X),parent(Z,Y).
```

Prolog Examples

- Factorial again.
- If we want Prolog to compute factorials, we need to tell it what factorials are.

```
factorial(0,1).

factorial(N,F) :-
    N>0,
    N1 is N-1,
    factorial(N1,F1),
    F is N * F1.
```

```
| ?- factorial(5,W).
W=120 ?
```

Fibonacci Revisited

```
f(0,1).
f(1,1).

f(N,F) :-
    N>0,
    N1 is N-1,
    N2 is N-2,
    f(N1,F1),
    f(N2,F2),
    F is F1 + F2.
```

```
f(N,F) :-c(N,_,_,F).

c(0,0,0,1).
c(1,0,1,1).
c(2,1,1,2).
c(N,P1,P2,P3):-
    N>2,
    N1 is N-1,
    c(N1, P0, P1, P2),
    P2 is P0+P1,
    P3 is P1+P2.
```

How about f(40,W)?

Ordered Clauses

```
factorial(0,1).

factorial(N,F) :-
    N>0,
    factorial(N1,F1),
    N1 is N-1,
    F is N * F1.

?-factorial(3,W).
```

Try these commands:

- `listing.`
- `trace.`
- `notrace.`

This wouldn't work, why?