Languages and Compilers (SProg og Oversættere)

Language Design

and Control structures

Language Design and control structures

a. Language Design Criteria
b. Relate language design criterial to the following consepts
c. Evaluation of expressions
d. Explicit vs. implicit sequence control
e. Loop constructs
f. Subprogram
g. Parameter mechanisms

Table 1.1 Language evaluation criteria and the characteristics that affect them

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

Sequence control

- Implicit and explicit sequence control
  - Expressions
    - Precedence rules
    - Associativity
    - Operand evaluation order
  - Statements
    - Sequence
    - Conditionals
    - Loop constructs
    - unstructured vs. structured sequence control
  - Subprograms
    - Parameter mechanisms

Expression Evaluation

- Determined by
  - operator evaluation order
  - operand evaluation order
- Operators:
  - Most operators are either infix or prefix (some languages have postfix)
  - Order of evaluation determined by operator precedence and associativity

Example

- What is the result for:

  3 + 4 * 5 + 6

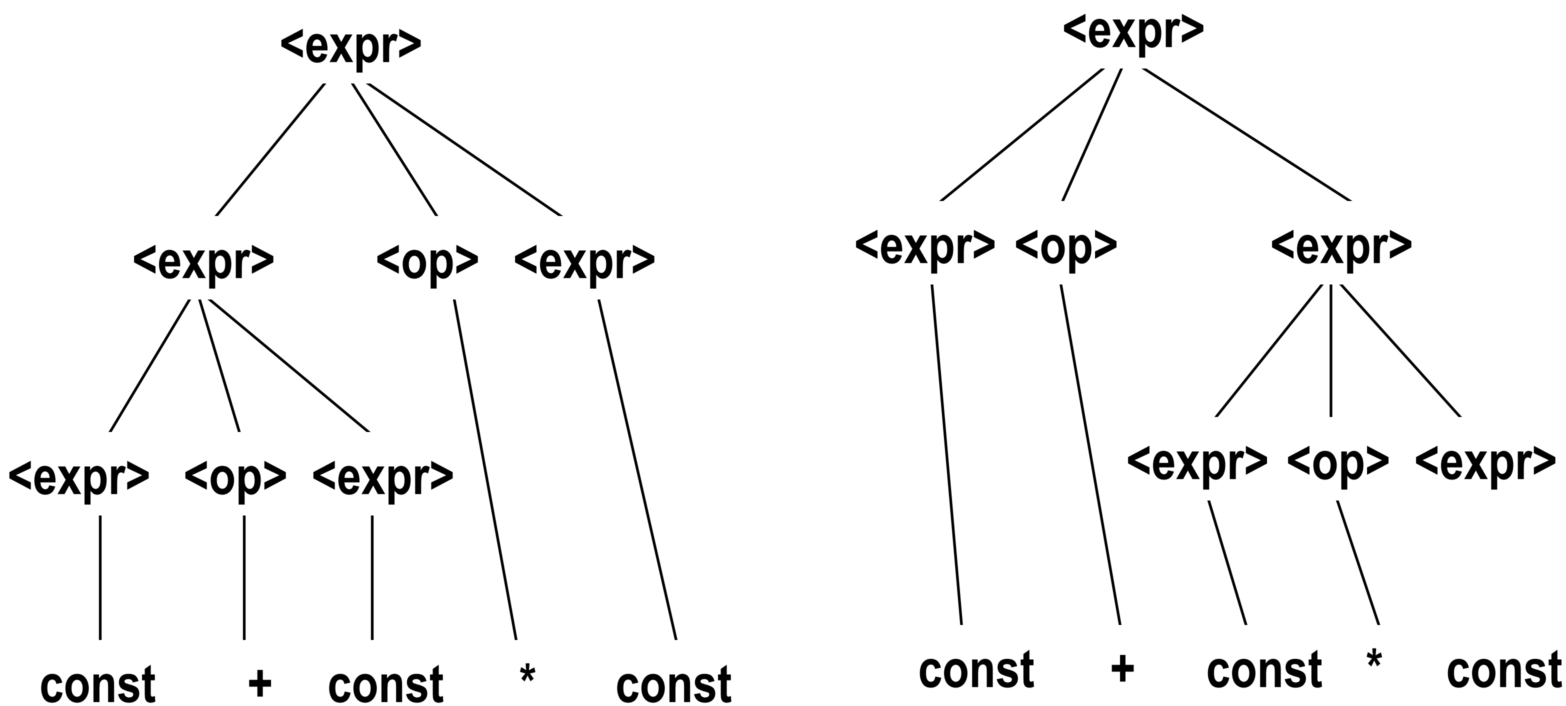
- Possible answers:
  - 41 = ((3 + 4) * 5) + 6
  - 47 = 3 + (4 * (5 + 6))
  - 29 = (3 + (4 * 5)) + 6 = 3 + ((4 * 5) + 6)
  - 77 = (3 + 4) * (5 + 6)
- In most language, 3 + 4 * 5 + 6 = 29
- … but it depends on the precedence of operators

An Ambiguous Expression Grammar

How to parse 3+4*5?

<expr> → <expr> <op> <expr> | const

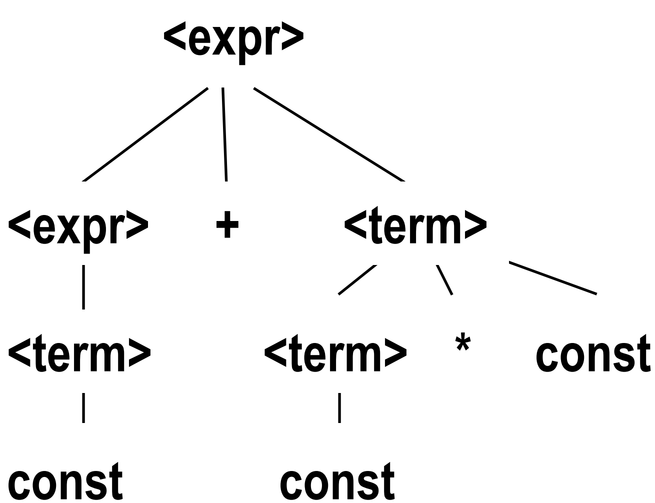
<op> → + | *



Expressing Precedence in grammar

- We can use the parse tree to indicate precedence levels of the operators

<expr> → <expr> + <term> | <term>
<term> → <term> * `const` | `const`



In LALR parsers we can specify Precedence which translates into Solving shift-reduce conflicts

Note in LL(1) parsers we have to use Left recursion elimination

Expr → Term Expr1 .
Expr1 →+ Term Expr1
| .
Term → const Term1 .
Term1 →* const Term1
| .

Operand Evaluation Order

- Example:

```
A := 5;
f(x) = {A := x+x; return x};
B := A + f(A);
```

- What is the value of B?
- 10 or 15?

Solution to Operand Evaluation Order

- Disallow all side-effects in expressions but allow in statements
  - Problem: not applicable in languages with nesting of expressions and statements
- Fix order of evaluation
  - SML does this – left to right
  - Problem: makes some compiler optimizations hard or impossible
- Leave it to the programmer to be sure the order doesn't matter
  - Problem: error prone

  - Fortress: Parallel evaluation unless specified to be sequential

Control of Statement Execution

- Sequential
- Conditional Selection
- Looping Construct
- Must have all three to provide full power of a Computing Machine

Conditional Selection

- Single-way
  - **`IF`** … **`THEN`** …
  - Controlled by boolean expression
- Two-way
  - **`IF`** … **`THEN`** … **`ELSE`**
  - Controlled by boolean expression
  - **`IF`** … **`THEN`** … usually treated as degenerate form of **`IF`** … **`THEN`** … **`ELSE`**
  - **`IF`**…**`THEN`** together with **`IF..THEN`**…**`ELSE`** require disambiguating associativity
- Multi-way
  - **`SWITCH`**
  - Typically controlled by scalar type
  - Each selection has own block of statements it executes

For-loops

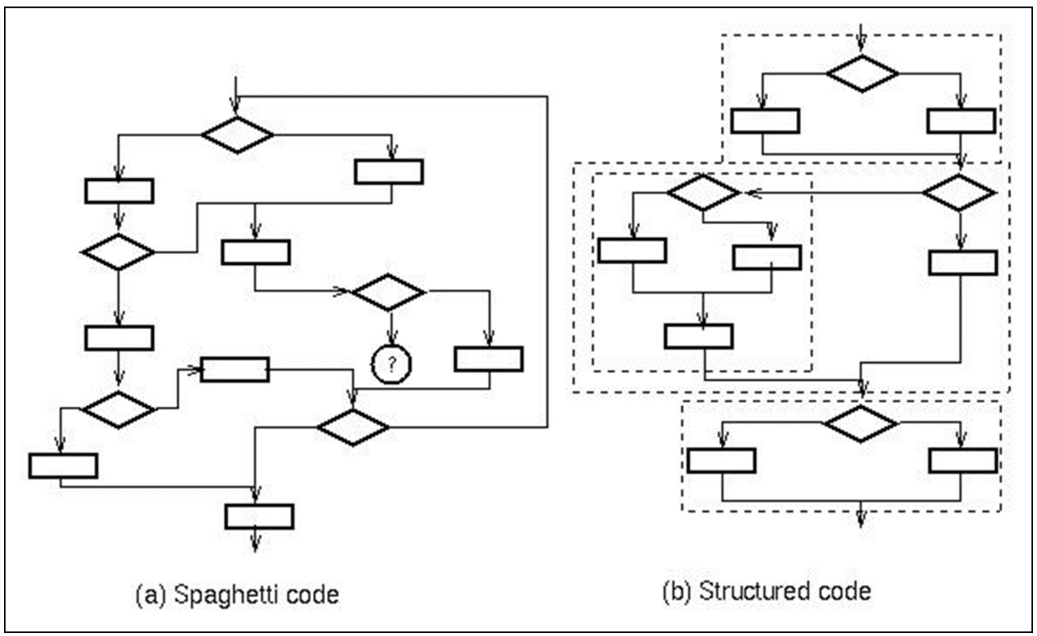
- Controlled by loop variable of scalar type with bounds and increment size
- Scope of loop variable?
  - Extent beyond loop?
  - Within loop?
- When are loop parameters calculated?
  - Once at start
  - At beginning of each pass

Logic-Test Iterators

- While-loops
  - Test performed before entry to loop
- **`repeat`**...**`until`** and **`do`**...**`while`**
  - Test performed at end of loop
  - Loop always executed at least once
- Design Issues:
  1. Pretest or posttest?
  2. Should this be a special case of the counting loop statement (or a separate statement)?

Gotos

- Requires notion of program point
- Transfers execution to given program point
- Basic construct in machine language
- Implements loops



Exceptions: Structured Exit

- Terminate part of computation
  - Jump out of construct
  - Pass data as part of jump
  - Return to most recent site set up to handle exception
  - Unnecessary activation records may be deallocated
    - May need to free heap space, other resources
- Two main language constructs
  - Declaration to establish exception *handler*
  - Statement or expression to *raise* or *throw* exception

Often used for unusual or exceptional condition, but not necessarily.

Subprograms

1. A subprogram has a single entry point
2. The caller is (normally) suspended during execution of the called subprogram
3. Control (normally) returns to the caller when the called subprogram's execution terminates

<u>*Functions or Procedures?*</u>

- Procedures provide user-defined statements
  - Abstractions over statements
- Functions provide user-defined operators
  - Abstractions over expressions
- Methods used for both functions and procedures

Subprogram Parameters

- Formal parameters: names (and types) of arguments to the subprogram used in defining the subprogram body
- Actual parameters: arguments supplied for formal parameters when subprogram is called
- *Actual/Formal Parameter Correspondence:*
  - attributes of variables are used to exchange information
    - Name – Call-by-name
    - Memory Location – Call-by reference
    - Value
      - Call-by-value (one way from actual to formal parameter)
      - Call-by-value-result (two ways between actual and formal parameter)
      - Call-by-result (one way from formal to actual parameter)

Tennent's Language Design principles

- The Principle of Abstraction
  - All major syntactic categories should have abstractions defined over them. For example, functions are abstractions over expressions
- The Principle of Correspondence
  - Declarations ≈ Parameters
- The Principle of Data Type Completeness
  - All data types should be first class without arbitrary restriction on their use

–Originally defined by R.D.Tennent

Example of missing correspondence

In Pascal:

```
procedure inc(var i : integer);
  begin
    i := i + 1
  end;

var x : integer;
begin
  x := 1;
  inc(x);
  writeln(x);
end
```

No corresponding declaration

However C has correspondence

```
void inc(int *i) {
  *i = *i + 1;
}

int x = 1;
inc(&x);
printf("%d", x);

int x = 1;
{
  int *i = &x;
  *i = *i + 1;
}
printf("%d", x);
```