Sequence Control

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Outline

Expressions

- An expression is a syntactic entity whose evaluation either:
  - produces a value
  - fails to terminate $\rightarrow$ undefined
- Examples

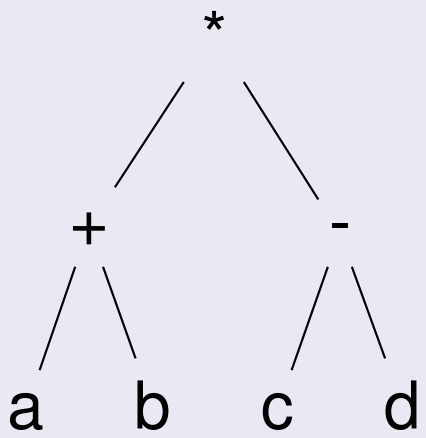
  4 + 3 * 2

  (a + b) * (c - a)

  (b != 0) ? (a/b) : 0

Expression Evaluation Mechanism

Expressions have functional composition nature



(a + b) * (c - d)

Expression Syntax

- Infix
- Prefix
- Postfix

Infix Notation

(a + b) * (c - d)

- Good for binary operators
- Used in most imperative programming language
- More than two operands?
  (b != 0) ? (a/b) : 0
- Smalltalk:
  myBox displayOn: myScreen at: 100@50

Precedence

3 + 4 * 5 = 23, not 35

- Evaluation priorities in mathematics
- Programming languages define their own precedence levels based on mathematics
- A bit different precedence rules among languages can be confusing

Associativity

- If operators have the same level of precedence, then apply associativity rules
- Mostly left-to-right, except exponentiation operator
- An expression contains only one operator
  - Mathematics: associative
  - Computer: optimization but potential problems
  - $10^{20} * 10^{20} * 10^{-20}$

Parentheses

- Alter the precedence and associativity
  (A + B) * C
- Using parentheses, a language can even omit precedence and associativity rules
  - APL
- Advantage: simple
- Disadvantage: writability and readability

Conditional Expressions

If statement

```
if (count == 0)
    average = 0;
else
    average = sum / count;
```

Conditional Expression

average = (count == 0) ? 0 : sum / count;

- C-based languages, Perl, JavaScript, Ruby

Prefix Notation

- Polish Prefix: * + a b - c d
- Cambridge Polish Prefix: (* (+ a b) (- c d))
- Normal Prefix: *(+(a,b),-(c,d))
  - Derived from mathematical function f(x,y)
  - Parentheses and precedence is no required, provided the -arity of operator is known
  - Mostly see in unary operators
  - LISP: (**append** a b c my_list)

Postfix Notation

- Polish Postfix: a b + c d - *
- Cambridge Polish Postfix: ((a b +) (c d -) *)
- Normal Postfix: ((a,b)+,(c,d)-)*
  - Common usage: factorial operator (5!)
  - Used in intermediate code by some compilers
  - PostScript: (Hello World!) **show**

Operand Evaluation Order

C program

```
int a = 5;
int fun1() {
    a = 17;
    return 3;
}
void main() {
    a = a + fun1();
}
```

What is the value of a? 8 20
Reason: Side-effect on the operand of the expression

Evaluation Mechanisms

- Eager evaluation
  - First evaluate all operands
  - Then operators
  - How about a == 0 ? b : b / a
- Lazy evaluation
  - Pass the un-evaluated operands to the operator
  - Operator decide which operands are required
  - Much more expensive than eager
- Lazy for conditional, eager for the rest

Short-Circuit Evaluation

$$(a == 0) \;||\; (b/a > 2)$$

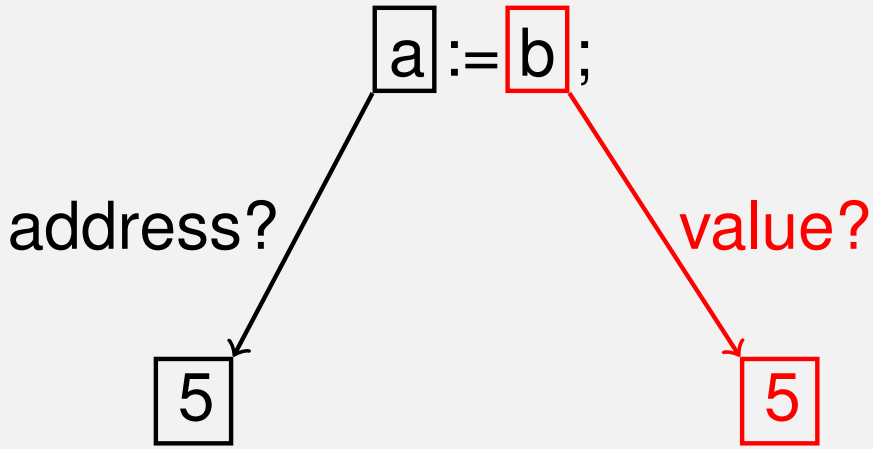
- If the first operand is evaluated as true, the second will be short-circuited
- Otherwise, "divide by zero"
- How about (a > b) || (b++ / 3) ?
- Some languages provide two sets of boolean operators: short- and non short-circuit
  - Ada: "and", "or" versus "and then", "or else"

Statements

- A statement is a syntactic entity whose evaluation:
  - does not return a value, but
  - changes the state of the system
- Example,
  a = 5;
  print "pippo"
  begin ... **end**

Assignment Statements

leftExpr AssignOperator rightExpr



- Evaluate left or right first is up to implementers

Assignment Statements

- C-based languages consider assignment as an expression

```
while ((ch = getchar()) != EOF) {...}
```

- Introduce compound and unary assignment operators (+=, -=, ++, –)
  - Increasing code legibility
  - Avoiding unforeseen side effects

Control Structures

- Control statements
  - Selecting among alternative control flow paths
  - Causing the repeated execution of sequences of statements
- Control structure is a control statement and the collection of its controlled statements

Two-way Selection

```
if control_expression
    then clause
    else clause
```

- Proved to be fundamental and essential parts of all programming languages

Dangling else

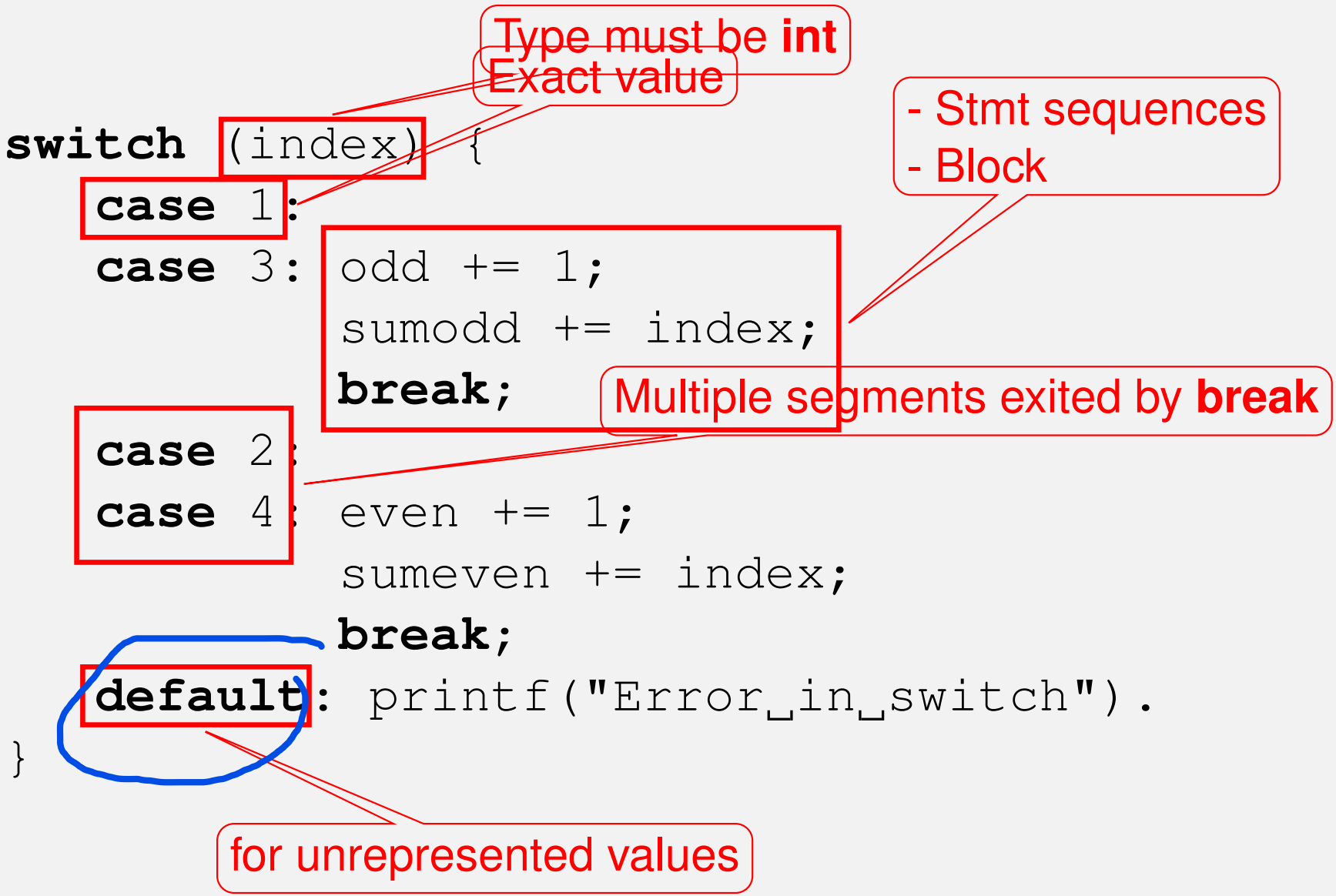
```
if (sum == 0)
    if (count == 0)
        result = 0;
    else
        result = 1;
```

- Solution: including block in every cases
- Not all languages have this problem
  - Fortran 95, Ada, Ruby: use a special word to end the statement
  - Python: indentation matters

Multiple-Selection

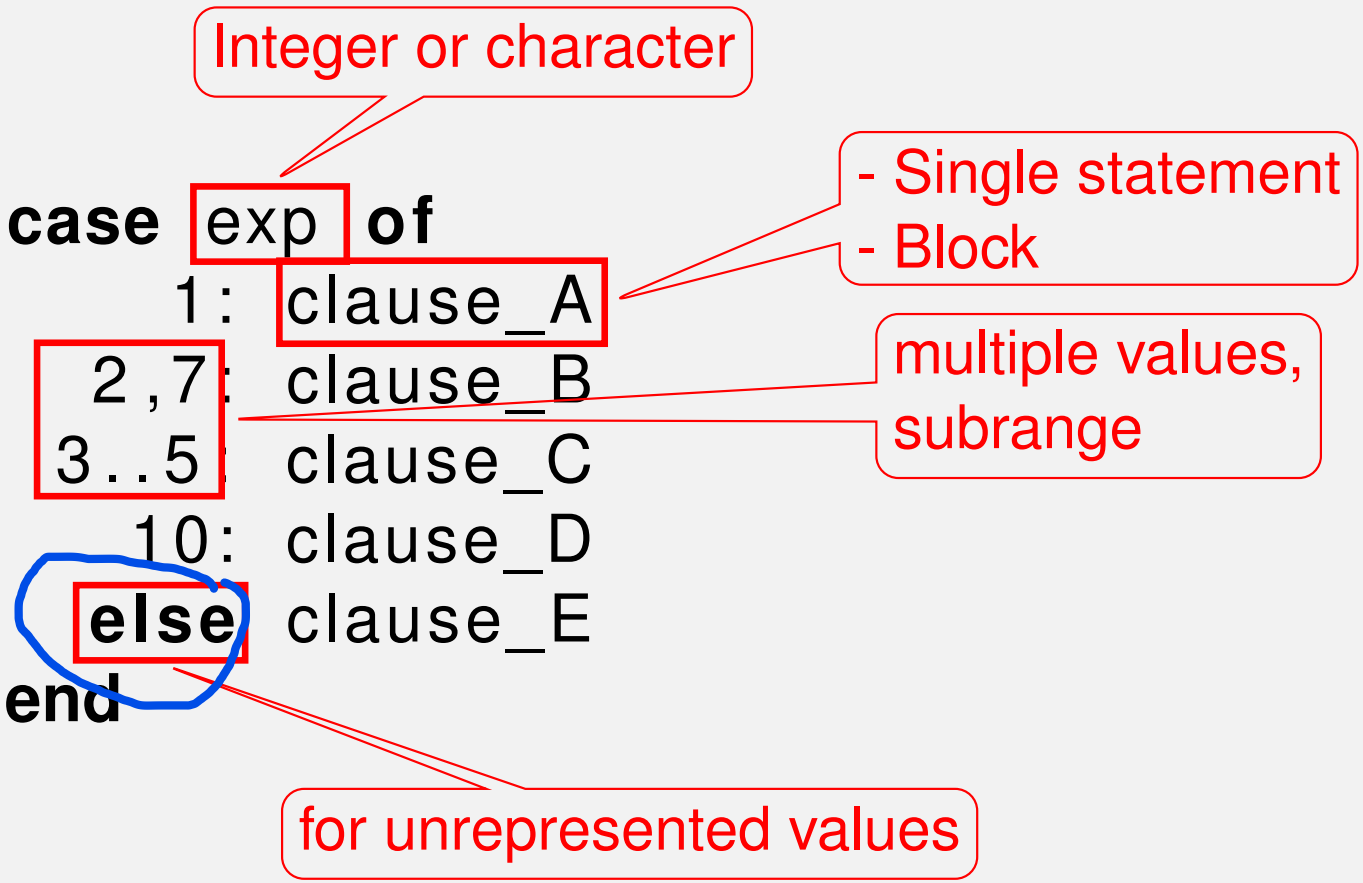
- Allows the selection of one of any number of statements or statement groups
- Perl, Python: don't have this
- Issues:
  - Type of selector expression?
  - How are selectable segments specified?
  - Execute only one segment or multiple segments?
  - How are case values specified?
  - What if values fall out of selectable segments?

Case Study: C




```
switch (index) {
   case 1:
   case 3: odd += 1;
           sumodd += index;
           break;
   case 2:
   case 4: even += 1;
           sumeven += index;
           break;
   default: printf("Error in switch").
}
```

Case Study: Pascal



Iterative Statements

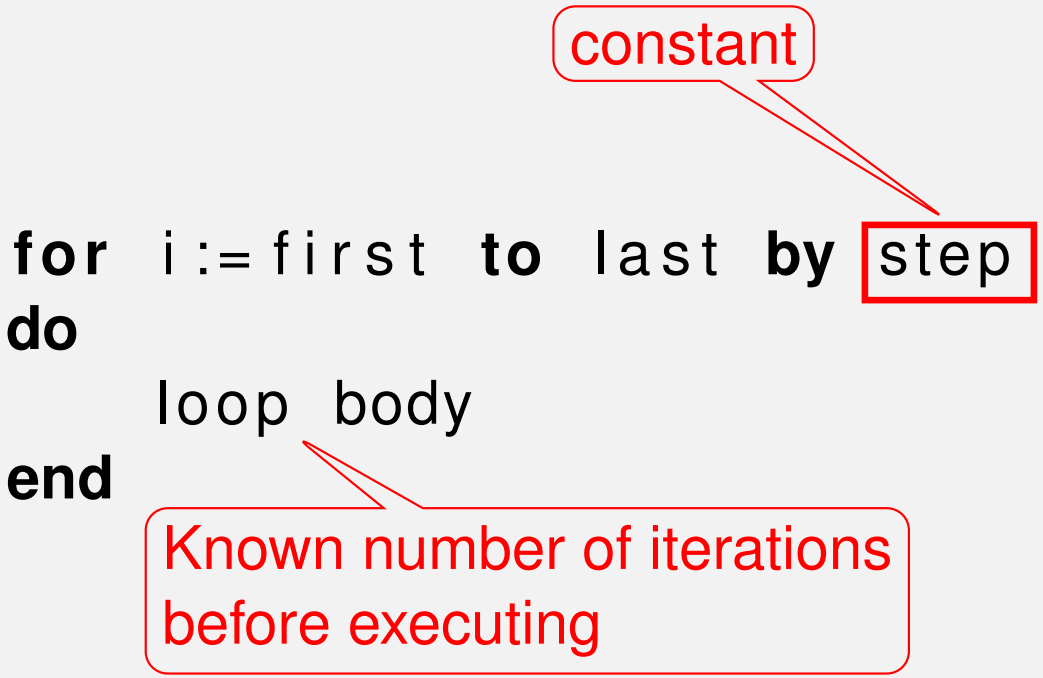
- Cause a statement or collection of statements to be executed zero, one or more times
- Essential for the power of the computer
  - Programs would be huge and inflexible
  - Large amounts of time to write
  - Mammoth amounts of memory to store
- Design questions:
  - How is iteration controlled?
    - Logic, counting
  - Where should the control appear in the loop?
    - Pretest and posttest

Counter-Controlled Loops

- Counter-controlled loops must have:
  - Loop variable
  - Initial and terminal values
  - Stepsize

Case Study: Algol-based

General form



Semantic

```
[define end_save]
end_save := last
i = first
loop:
if i > end_save goto out
[loop body]
i := i + step
goto loop
out:
[undefine end_save]
```

Case study: C

General form

```
for (expr_1; expr_2; expr_3)
    loop body
```

Can be infinite loop

Semantic

```
        expr_1
      loop:
if expr_2 = 0 goto out
    [loop body]
        expr_3
     goto loop
     out: ...
```

Logically Controlled Loops

- Repeat based on Boolean expression rather than a counter
- Are more general than counter-controlled
- Design issues:
  - Should the control be pretest or posttest?
  - Should the logically controlled loop be a special form of a counting loop or a separate statement?

Case Study: C

Forms	Semantics
while (ctrl_expr) loop body	loop: if ctrl_expr is false goto out [loop body] goto loop out:...
do loop body **while** (ctrl_expr);	loop: [loop body] if ctrl_expr goto loop

User-Located Loop Control

- Programmer can choose a location for loop control rather than top or bottom
- Simple design: infinite loops but include user-located loop exits
- Languages have exit statements: **break** and **continue**
- A need for restricted goto statement

Case Study: C

```
while (sum < 1000) {
    getnext(value);
    if (value < 0) break;
    sum += value;
}
```

- What if we replace **break** by **continue**?

Iteration Based on Data Structures

- Controlled by the number of elements in a data structure
- Iterator:
  - Called at the beginning of each iteration
  - Returns an element each time it is called in some specific order
- Pre-defined or user-defined iterator

Case Study: Java

```
ArrayList al = new ArrayList();
...
Iterator it = al.iterator();
while (it.hasNext()) {
    Object element = it.next();
    ...
}
```

```
String[] strList = {"Bob","Carol","Ted"};
...
foreach (String name in strList)
      Console.WriteLine("Name:{0}", name);
```

Unconditional Branching

- Unconditional branch, or goto, is the most powerful statement for controlling the flow of execution of a program's statements
- Dangerous: difficult to read, as the result, highly unreliable and costly to maintain
- Structured programming: say no to goto
- Java, Python, Ruby: no goto
- It still exists in form of loop exit, but they are severely restricted gotos.

to be continued

Summary

- Expressions
  - Operator precedence and associativity
  - Side effects
- Statements
  - Assignment
  - Selection Statement
  - Loop structures