Part III

Expressions

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Expressions

An *expression* is a *combination* of at least one *value*, *constant*, *variable*, *operator*, and *function* to perform a computation, i.e., to *evaluate* another value.

Order of evaluation (evaluation of operands, subexpressions,...) is *determined* by

- *precedence rules*
- *association rules*.

```
(x + 3 * f(x));
```

example

Value Categories (1)

lvalue

One property of expressions in C is value category classes: lvalue, rvalue, and function designator

- lvalue expressions („left value“)
  - any expression not returning `void` i.e., a particular value is returned:
    - identifiers, e.g., `i`
    - string literals, e.g., `"Hello World"`
    - compound literals, e.g., `(const char []){"abc"}`
    - parenting lvalue expressions, e.g., `(i + 5)`
    - result of member access operator if left-side operand is lvalue, e.g., `my_struct.x`
    - result of member access operator by pointer, e.g., `my_struct_ptr->x`
    - result of dereferencing a memory address, e.g., `*my_struct_ptr`
    - result of array element getter operator, e.g., `my_array[23]`
  - the following cases, lvalue expressions may be used as replacement for `x`
    - the operand for taking the memory address, i.e., `&x`
    - the operand for increment/decrement operators, i.e., `i++`
    - left-side operand for member access operator, i.e., `x.y`
    - left-side operand for assignment, i.e., `x = x + y`
    - left-side operand for compound assignment, i.e., `x += y`
  - In most cases, lvalue expression lead directly to a value memory load

taken from: http://en.cppreference.com/w/c/language/value_category

Value Categories (2)

lvalue

One property of expression in C is value category classes: lvalue, rvalue, and function designator

- lvalue expressions („left value“)
  - lvalue expressions are *mutable* unless
    - they are from type array and marked as *immutable* (via `const` keyword)
    - they are of an incomplete type (see later)
    - they are a struct/union type having (recursively) one *immutable* member (via `const`)

based on: http://en.cppreference.com/w/c/language/value_category

Value Categories (3)

rvalue

One property of expression in C is value category classes: lvalue, rvalue, and function designator

- rvalue expressions („right value“)
  - expressions that evaluate to values that have no object identity or storage location:
    - constants (integer, character, constants), e.g., 23L
    - all operators that do not return lvalues, examples (not complete):
      - case expression, e.g., (float)
      - arithmetic, comparison, logical and bitwise operators, e.g., +
      - increment/decrement operators, e.g., ++
      - assignment & compound assignment operators, e.g., +=
      - …
  - address of a rvalue expressions cannot be taken

taken from: http://en.cppreference.com/w/c/language/value_category

Value Categories (4)

function designator

One property of expression in C is value category classes: lvalue, rvalue, and function designator

- function designator expressions (function name)
  - expression of type function
  - function designators convert into pointer to function

```
void foo() { }
main() { printf("%p", foo); }
```

Output example
0x105664e70

%p in printf is the format to print memory addresses

taken from: http://en.cppreference.com/w/c/language/value_category

Arithmetic Operators

- `+y` unary plus: the value of y
- `-y` unary minus: the negative value of y
- `x + y` addition: the addition of x and y
- `x - y` subtraction: the subtraction of y from x
- `x * y` product: the product of x and y
- `x / y` division: the division of x by y
- `x % y` modulo: the remainder of division of x by y

based on: http://en.cppreference.com/w/c/language/operator_assignment

Increment/Decrement Operators

- `y++` **postfix increment**: y gets its value **plus 1**
- `y--` **postfix decrement**: y gets its value **minus 1**

→ *evaluates to value of* `y`

y must be a mutable lvalue expression resulting in number or pointer type

- `++y` **prefix increment**: y gets its value **plus 1**
- `--y` **prefix decrement**: y gets its value **minus 1**

→ *evaluates to value of* `y+=1` resp. `y-=1`

value of `y` is incremented/ decremented by 1

Example

```
int a = 42;
int b = a++; // b == 42 and a == 43

int a = 42;
int b = ++a; // b == 43 and a == 43
```

based on: http://en.cppreference.com/w/c/language/operator_assignment

Comparison Operators

Comparison („relational“) operators result in boolean value:
1 (`true`) if condition holds
0 (`false`) otherwise

- `x == y` equality: is x equal to y?
- `x != y` inequality: is x not equal to y?
- `x < y` less than: is x less than y?
- `x > y` greater than: is x greater than y?
- `x <= y` less than or equal to: is x less than or equal to y?
- `x >= y` greater than or equal to: is x greater or equal to y?

based on: http://en.cppreference.com/w/c/language/operator_assignment

Logical Operators

Implementation of standard boolean algebra operations

- `!y` logical NOT: logical negation of y
- `x && y` logical AND: logical AND of x and y
- `x || y` logical OR: logical OR of x and y

based on: http://en.cppreference.com/w/c/language/operator_assignment

Bitwise Arithmetic Operators

Implementation of standard bitwise arithmetic operators

- `~y` bitwise NOT: bitwise NOT of y
- `x & y` bitwise AND: bitwise AND of x and y
- `x | y` bitwise OR: bitwise OR of x and y
- `x ^ y` bitwise XOR: bitwise XOR of x and y
- `x << y` bitwise left shift : x left shifted by y
- `x >> y` bitwise right shift: x right shifted by y

based on: http://en.cppreference.com/w/c/language/operator_assignment

Assignment Operators

- `y = x` — **basic assignment**: y gets the value of x
  y is mutable lvalue expression and x is implicitly convertible to or compatible with type of y

compound assignment

- `y += x` — **addition assignment**: y gets its own value **plus** x
- `y -= x` — **subtraction assignment**: y gets its own value **minus** x
- `y *= x` — **multiplication assignment**: y gets its own value **multiplied** by x
- `y /= x` — **division assignment**: y gets its own value **divided** by x
- `y %= x` — **modulo assignment**: y gets its own value **modulo** x
- `y &= x` — **bitwise AND assignment**: y gets the value of **bitwise AND** of its own value and x
- `y |= x` — **bitwise OR assignment**: y gets the value of **bitwise OR** of its own value and x
- `y ^= x` — **bitwise XOR assignment**: y gets the value of **bitwise XOR** of its own value and x
- `y <<= x` — **bitwise left shift assignment**: y gets the value y **left shifted** by x
- `y >>= x` — **bitwise right shift assignment**: y gets the value y **right shifted** by x

taken from: http://en.cppreference.com/w/c/language/operator_assignment

Member Access Operators

Member access operators give access to members of their operands (arrays, pointers,...)

more details here, when we talk about arrays and pointers

- `x[y]` **array subscript**: get the y-th element in array x
- `*y` **pointer dereference**: dereference pointer to y in order to get object/function at address stored in y
- `&y` **address of**: get (memory) address of object/function and create pointer with that address
- `x.y` **member access**: get the member called y in the struct/union x
- `x->y` **member access by pointer**: get member called y in struct/union which is pointed by x

based on: http://en.cppreference.com/w/c/language/operator_assignment

Other Operators

- `f(…)` — function call: call function *f* with arguments given by …
- `x, y` — comma: evaluate expression *x*, throw away its result, evaluate expression *y*, return its type and value from evaluation of *y* `int y; foo((y=3, y+2));` ≡ `int y = 3; foo((y+2));`
- `(x)y` — type cast: perform explicit type conversion for *y* to type *x*
- `x?y:z` — conditional operator: if expression *x* evaluates to non-zero, evaluate *y* otherwise *z*
- `sizeof(y)` — sizeof operator: get size in bytes of *y*
- `_Alignof(y)` — alignof operator: get alignment requirements of *y*

taken from: http://en.cppreference.com/w/c/language/operator_other

Precedences

A table for operator precedences can be found here:
http://en.cppreference.com/w/c/language/operator_precedence