Express Yourself

- Expressions: combining named entities
  - Expression notation
    - Operators and operands
    - Functions
  - Precedence and associativity

- Assignment and variables
  - Functional vs. side-effect
  - Value vs. reference
  - Initialization
  - Assignment operators

- Evaluating expressions
  - Evaluation order
  - Short-circuiting

Expression Notation

- Constants, literals, or variables
- Operators, functions
  - One and the same in some languages: Ada, C++

- Notation refers to where the function or operator is placed relative to its arguments or operands
  - Prefix
    - Function calls in many languages — `function_name(arg1, arg2, arg3)`
    - `"+"(a, b)` (Ada)
    - `!"cancel".equals(inputStr)` (Java)
    - `(* (+ 2 5) 10)` (Lisp)
    - `twice multiply 3` (ML)
  - Infix
    - Binary operators in many languages — `a + b`, `x ** y`, `p << 2`, `flags & SETTING_BIT`
    - `fileDialog openOnDirectory: dir withFileTypes: types` (Smalltalk, Objective-C)
    - `x = if j > 0 then x + 1 else x - 1` (Algol family)
    - `x = (j > 0) ? x + 1 : x - 1` (C and relatives)
  - Postfix
    - `pointer^` (Pascal)
    - `z++` (C and relatives)
    - `1 inch 1 inch moveto` (PostScript)

Precedence

- Infix notation can lead to ambiguity on what should be done first
  - In Fortran, is `a + b * c ** d ** e / f`…
    - `((((a + b) * c) ** d) ** e) / f` ? or
    - `a + (((b * c) ** d) ** (e / f))` ? or
    - `a + ((b * (c ** (d ** e))) / f)` ?
  - In Smalltalk or Objective-C, is `shape containing: aShape intersects: anotherShape`…
    - `[shape containing: aShape] intersects: anotherShape` ? or
    - `shape containing: [aShape intersects: anotherShape]` ? or
    - `shape containing: aShape intersects: anotherShape` ?

- Typical conventions:
  - Multiplication/division precede addition/subtraction
  - Boolean operators group after arithmetic operators
  - Unary operators precede binary operators
  - Some details in Scott's Figure 6.1

- Precedence can be implied by the grammar and thus the parser, though this is not absolutely necessary

Associativity

- Mostly left-to-right: 2 + 3 – 4 – 5 is…
  - ((2 + 3) – 4) – 5 = –4, not
  - 2 + (3 – (4 – 5)) = 6

- Exponentiation (**)
  - Fortran: right-associative — 4**3**2 = 4**(3**2)
  - Ada: *not* associative — parentheses required

- Assignment
  - C, which allows concatenation of assignments, $a = b = a + c$, is right-associative
    - Calculate $a + c$ first, assign to b, then assign to a
  - Speaking of assignment…

Assignment

- Functional vs. imperative languages
  - Functional minimizes the need for state: computation is done by evaluation of an expression at a given time; recursion is frequently used
  - Imperative languages iterate more, and so require *side effects* — changes to values that persist across the program
    - Side effects introduce a distinction between *functions* — constructs that return a value — and *statements* — constructs whose value lie in their side effects
    - Imperative programming as "computing by means of side effects"
    - That is where variables, and assignments to variables, come in

- Anatomy of an assignment
  - *lvalue <assignment_op> rvalue*
  - An *l-value* is any expression to which an expression can be assigned
  - The *assignment_op* is the token for assignment (typically "=" or ":=")
    - If you're a stickler for these things, an assignment *a* = *b* should be read "*a* gets *b*," not "*a* equals *b*"
  - An *r-value* is any expression that can be assigned to an *l-value*

L-value and R-value Examples

`x = y + z;` (most languages where "=" is the assignment token)

`x := x + 2;` (most languages where ":=" is the assignment token)

`a[5] = "Item".substring(2);` (Java)

`buf[i][calculateColumn(id)] = buf[i - 1][priorColumn] << 4;` (C et. al.)

`val currentTuple = (5, 7);` (ML)

`val (x, y, z) = (10, 9, "center");` (ML)

`a := Array fromCollection: c.` (Smalltalk…note the period)

`my ($arg1, $arg2) = @_;` (Perl)

`f[4]->id.tail = g[2]->postfix;` (C et. al.)

`@list = qw/Tom Dick Harry/;` (Perl)

`byte b[] = { 0, 5, (byte)0x23, (byte)0xaa };` (Java)

Variables: Values vs. References

- Note Scott's Figure 6.2
- "Copy" vs. "point"

- Distinction is often implicit
  - Java: based on primitive type vs. class
  - Smalltalk: it's *always* by reference
  - ML: distinction is required

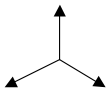
```
val x = 5;
val xref = ref x;
val x = x + 2;      (* x is now 7; !xref is still 5 *)
xref := x + 3;      (* note no declaration; !xref is now 10 *)
```

  - C and C++ can derive references from values when applicable

```
int x = 5;
int *xref = &x;
x = x + 2;          /* x is now 7; so is *xref */
xref = x + 3;       /* Watch out!!! In most compilers this is a warning. */
```

Orthogonality

- Introduced as a design goal in Algol 68
- Orthogonal features…
  - can be used in any combination
  - are meaningful in all combinations of those features
  - have consistent meaning regardless of how they are combined
- Directly related to geometric orthogonality



- Examples
  - Allowing all "statements" to be used as expressions
    - *if…then…else*
    - nested statement blocks
    - giving assignments a value (usually the r-value)

Initialization

- Combining declaration and assignment

```
int x = 5;
val xref = ref (x + y);
void *buf = malloc(1024);
```

- Aggregates: a language's ability to specify literals for more complicated types (arrays, structures)

```
String[] names = { "Tom", "Dick", "Harry" };

my @commands = qw/Open Close Save Quit/;

struct SubRec { double x; double y; }
struct Rec { int a; SubRec sr; int b; }
Rec r = { 5, { 5.0, -1.5}, 10 };
```

- Constructors: parameterized and encapsulated initialization for aggregate types (including object-oriented classes)

```
MyClass c = new MyClass(5, 7, false);
```

- Implicit initialization?
  - C always sets values to zero; Java specifies detection of assignment
  - Explicitly undefined values: *null*, *NIL*, *NaN* (not-a-number)

Combination Assignments

- Simultaneous "operate-and-assign"

```
x += 5;
i /= calcDivisor() + 3;
j++;
s += " thought".substring(3);
```

- Not just syntactic sugar!
  - Avoids repeated (and possibly incorrect) function calls and/or memory accesses and dereferencing

```
tokens[getIndex()] = tokens[getIndex()] + " private";
r.a[i].value = r.a[i].value * alpha;
```

- C has pre- and post- combos, ++ and – –
  - Assign the new value either before or after the expression is evaluated
    - `a[++index]` vs. `a[index++]`
- ML, Perl, and Clu allow tuple-like assignments

```
my ($x, $y) = (5, 3); ($x, $y) = ($y, $x);
```

Evaluation Order

- Not the same as determining precedence or associativity:

```
my $j = 0;
sub getIndex { $j++; return $j; }
my $result = $j - getIndex() + $j;          # $result gets 1.
```

- Watch out for side effects
  - Danger zone: rearranging floating point arithmetic

- May affect code improvement
  - Register allocation
  - Instruction scheduling
  - Memory accesses

- Typically, evaluation order is undefined
  - Exception: Java — evaluation is left-to-right
    - What if the above fragment were written in Java?

Short-Circuit Booleans

- Sometimes we know the result of a boolean expression before we evaluate the entire expression; short-circuiting bails out once we know the result

```
if ((x != 0) && ((y == 5) || ("".equals(response)))) ...
```

- May improve performance and avoid otherwise erroneous states

```
if (unlikely_condition && expensive_function()) ...
```

```
while ((p != null) && (p.getCount() > 0)) ...
```

```
for (Iterator it = aList.iterator(); it.hasNext() && !"".equals(it.next()); ) ...
```

- Watch out for when short-circuiting results in incorrect computation: Scott, Figure 6.3
  - Clu, Ada, C, C++, and Java allow explicit short-circuiting (or not):
    - Clu: `and`/`or` vs. `cand`/`cor`
    - Ada: `and`/`or` vs. `and then`/`or else`
    - C, C++, Java: `&&` / `||` vs. `&` / `|` (on booleans in Java)