We have…

- ...scanned and parsed and type checked and built an abstract syntax tree with a symbol table...
- So we know we have
  - a correct program, and
  - we have a useful representation of that program
- Now what?
  - Generate equivalent code in a lower-level language … (so we can later run it)
  - Perform further analysis .. (such as?)
  - …what else?

Why interpret vs. generate code?

- Time until program can be executed
- Speed of executing program
- Simplicity of implementation
- Flexibility of implementation

TRADEOFFS

Interpreters

- Create data structures to represent run-time program state
  - values manipulated by program
  - activation record (i.e., stack frame) for each called method
  - environment to store local variable bindings
  - pointer to lexically-enclosing activation record/environment (static link)
  - pointer to calling activation record (dynamic link)
- EVAL loop executing AST nodes

An Interpreter for MiniJava:

- readme (Evaluator subdirectory)
  - The main data structure is the environment, which keeps track of the values of local variables declared in a given scope, plus some information about declarations in classes.
  - Environments closely parallel SymbolTables
    - "compile-time" information computable before running the program (e.g. declarations and types)
    - "run-time" information representing the program’s running state
  - Only one symbol table for each program scope, while there can be zero or more environments created for (most) scopes
Continued... ~readme

- There are environments for different kinds of scopes (global scope, class scope, and code scope…), as they have different declarations and run-time state.
  - An activation record is an instance of an environment
- The (only) global environment maps names of classes to the corresponding class environments…
- A class environment maps the names of locally declared methods to their declarations and the names of locally declared instance variables to their resolved types. Also stores a reference to the environment of its superclass (if any).

Continued ~readme

- The values of the instance variables are not stored in the class environment because each instance of the class stores its own values of its instance variables.
- A code environment maps the names of local variables to their current values.
- A method code environment additionally remembers the environment of its caller, for use in printing stack traces during evaluation.
- Each kind of nested environment stores a reference to its lexically enclosing scope's environment.

Activation Records

- Each call of a procedure allocates an activation record that stores
  - mapping from names to Values, for each formal and local variable in that scope (environment)
  - lexically enclosing activation record (static link)
- An activation record for a method also stores the calling activation record (dynamic link)
- A class activation record also stores
  - methods (to support run-time method lookup)
  - instance variable declarations, not values
  - values stored in class instances (ClassValues)

Activation Records vs Symbol Tables

- For each method/nested block scope in a program:
  - exactly one symbol table, storing types of names
  - possibly many activation records, one per invocation, each storing values of names
- For recursive procedures,
  - can have several activation records for same procedure on stack simultaneously
  - All of these activation records have same "shape," described by single symbol table

Example

class Fac {
    public int ComputeFac(int num) {
        int numAux;
        if (num < 1) {
            numAux = 1;
        } else {
            numAux = num * this.ComputeFac(num-1);
        }
        return numAux;
    }
}
Interpretation tradeoffs: reprise

- Simple conceptually, easy to implement
  - Fast turnaround time
  - Good programming environments
  - Easy to support fancy language features
- Slow to execute
  - Data structure for value vs. direct value
  - Variable lookup vs. registers or direct access
  - EVAL overhead vs. direct machine instructions
  - No optimizations across AST nodes

Compile-time Processing

- Decide representation of run-time data values
- Decide where data will be stored
  - Registers
  - Format of stack frames
  - Global memory
  - Format of in-memory data structures (e.g. records, arrays)
- Generate machine code to do basic operations
  - Just like interpreting expression, except generate code that will evaluate it later
- Do optimizations across instructions if desired

Compile-time vs Run-time

<table>
<thead>
<tr>
<th>Compile-time</th>
<th>Run-time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Procedure</td>
<td>Activation record/stack frame</td>
</tr>
<tr>
<td>Scope, symbol table</td>
<td>Environment (contents of stack frame)</td>
</tr>
<tr>
<td>Variable</td>
<td>Memory location or register</td>
</tr>
<tr>
<td>Lexically-enclosing scope</td>
<td>Static link</td>
</tr>
<tr>
<td>Calling Procedure</td>
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