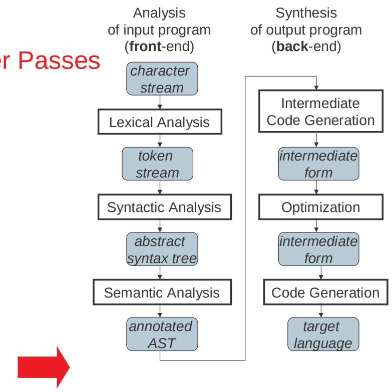
Building An Interpreter

After having done all of the analysis, it's possible to run the program directly rather than compile it … and it may be worth it

Compiler Passes



Implementing A Language

Given type-checked AST program representation:
- might want to run it
- might want to analyze program properties
- might want to display aspects of program on screen for user
- ...

To run program:
- can interpret AST directly
- can generate target program that is then run recursively

Tradeoffs:
- time till program can be executed (turnaround time)
- speed of executing program
- simplicity of implementation
- flexibility of implementation

Interpreters

Create data structures to represent run-time program state
- values manipulated by program
- **activation record** (a\k\a 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

Pros and Cons of Interpretation

\+ 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

Compilation

Divide interpreter work into two parts:
- compile-time
- run-time

Compile-time does preprocessing
- perform some computations at compile-time once
- produce an equivalent program that gets run many times

Only advantage over interpreters: faster running programs

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

Compile-time	Run-time
Procedure	Activation record/stack frame
Scope, symbol table	Environment (contents of stack frame)
Variable	Memory location or register
Lexically-enclosing scope	Static link
Calling Procedure	Dynamic link

Static Link vs Dynamic Link

```
class C {
   int x;
   boolean y;
   int f(int i) {
       int z;
       ...
       {
          boolean x;
          C z;
          int f;
               ...f(...)  ...  f(...)...
       }
       ...f(...) ...
    }
 }
```

An Interpreter for MiniJava

In `Environment` subdirectory, two data structures:

Data structure to represent run-time values: `Value` hierarchy
- analogous to `ResolvedType` hierarchy

`Value`
- `IntValue`
- `BooleanValue`
- `ClassValue`
- `NullValue`

MiniJava Interpreter [continued]

Data structure to store `Values` for each variable: `Environment` hierarchy
- analogous to `Symbol Table` hierarchy

`Environment`
- `GlobalEnvironment`
- `NestedEnvironment`
  - `ClassEnvironment`
  - `CodeEnvironment`
    - `MethodEnvironment`

- `evaluate` methods for each kind of AST class

Activation Records

Each call of a procedure allocates an activation record (instance of Environment, somewhat poorly named)
- Activation record stores:
  - mapping from names to `Values`, for each formal and local variable in that scope (**environment**)
  - lexically enclosing activation record (**static link**)
- Method activation record: also
  - calling activation record (**dynamic link**)
- Class activation record: also
  - methods (to support run-time method lookup)
  - instance variable declarations, not values
  - values stored in class instances, i.e.,`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 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;
   }
}
```