CS 153: Concepts of Compiler Design

October 5 Class Meeting

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Reminders

- A VARIABLE node in the parse tree contains a pointer to the variable name's symbol table entry.
  - Set in the front end by method `VariableParser.parse()`
  - The method that takes two parameters.
- A symbol table entry contains a pointer to its parent symbol table.
  - The symbol table that contains the entry.

Reminders, *cont'd*

- Each symbol table has a nesting level field.
- Therefore, at run time, for a given VARIABLE node, the executor can determine the nesting level of the variable.

Runtime Access to Nonlocal Variables

```
PROGRAM main1;
VAR i, j : integer;

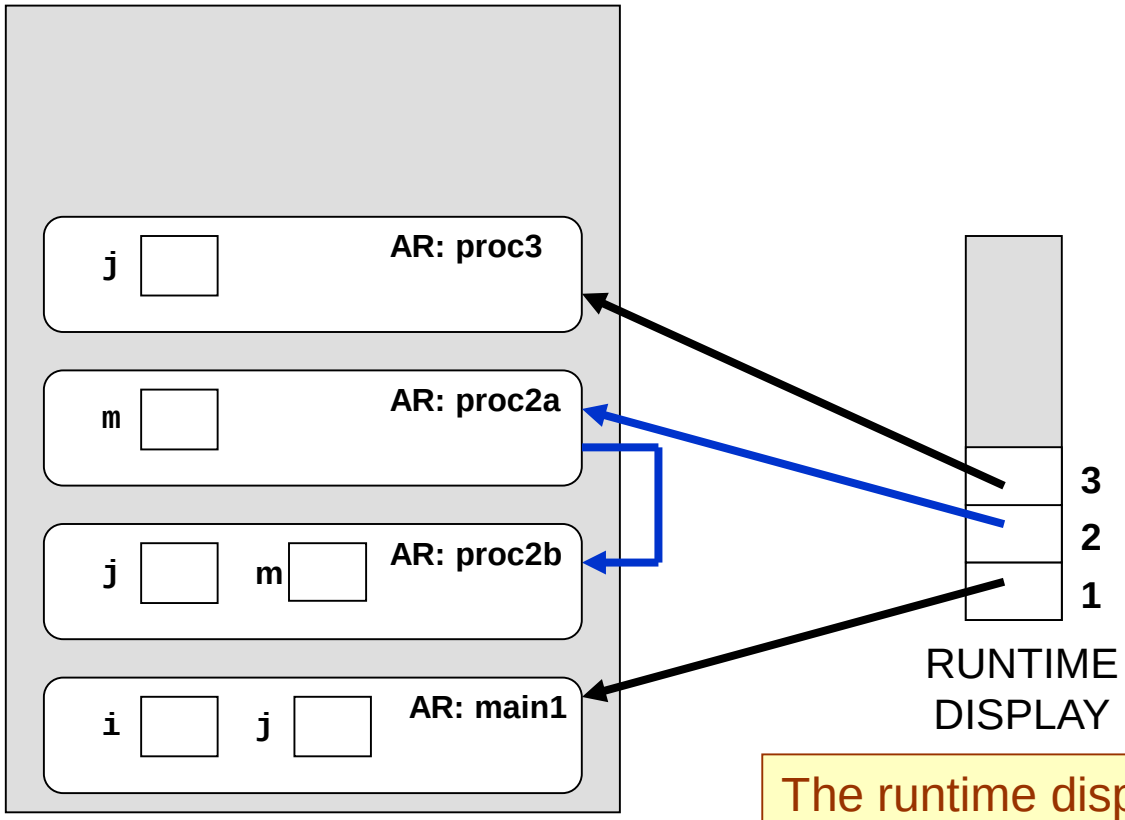
PROCEDURE proc2a;
  VAR m : integer;

  PROCEDURE proc3;
      VAR j : integer
      BEGIN
        j := i + m;
      END;

  BEGIN {proc2a}
    i := 11;
    m := j;
    proc3;
  END;

PROCEDURE proc2b;
  VAR j, m : integer;
  BEGIN
    j := 14;
    m := 5;
    proc2a;
  END;

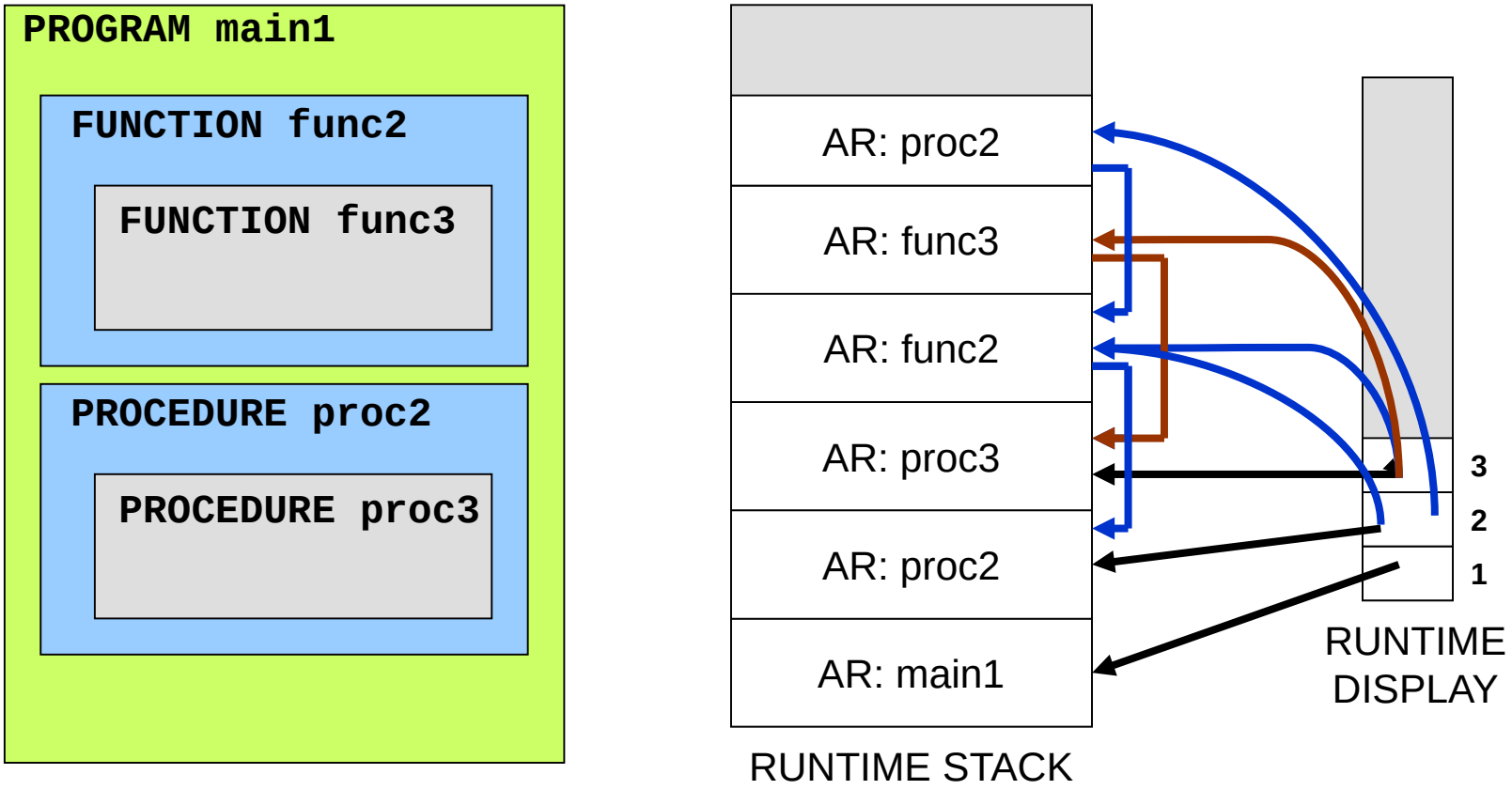
BEGIN {main1}
  i := 33;
  j := 55;
  proc2b;
END.
```



The runtime display allows faster access to **nonlocal** values.

main1 → proc2b → proc2a → proc3

Recursive Calls

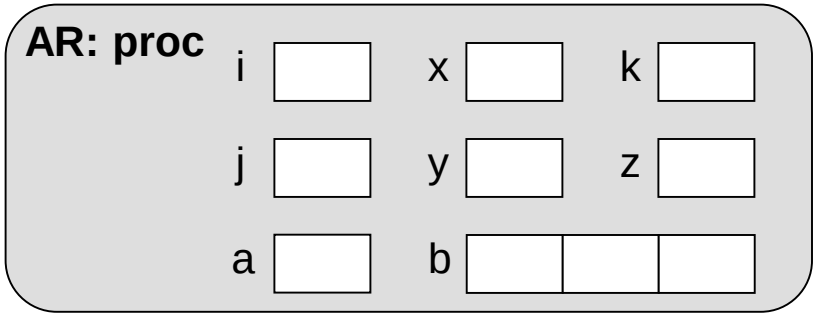


main1 ➔ proc2 ➔ proc3 ➔ func2 ➔ func3 ➔ proc2

Allocating an Activation Record

- The activation record for a routine (procedure, function, or the main program) needs one or more "data cells" to store the value of each of the routine's local variables and formal parameters.

```
TYPE arr = ARRAY[1..3] OF integer;
...
PROCEDURE proc(i, j : integer;
               VAR x, y : real;
               VAR a : arr;
               b : arr);
VAR
    k : integer;
    z : real;
```



Allocating an Activation Record

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TYPE arr = ARRAY[1..3] OF integer;
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PROCEDURE proc(i, j : integer;
               VAR x, y : real;
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    k : integer;
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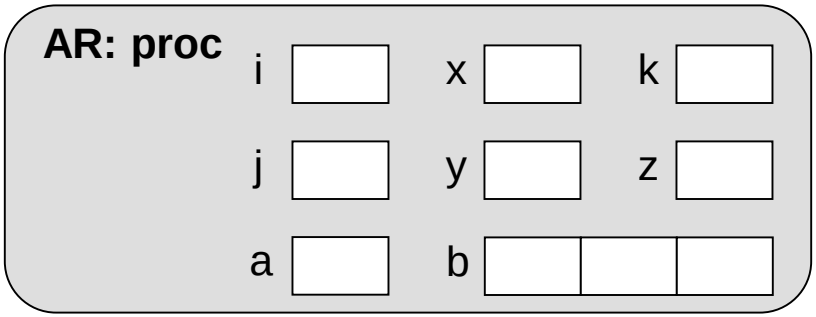
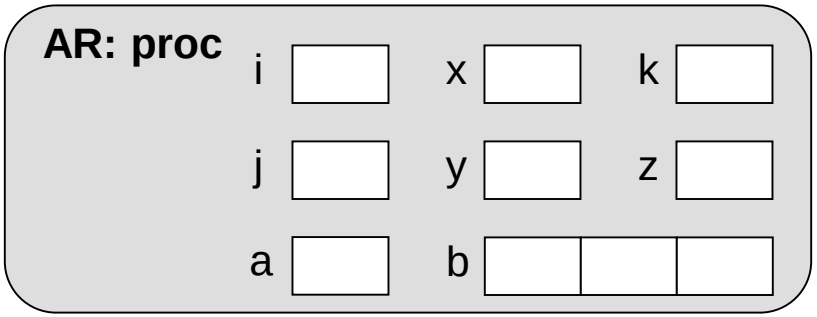
```



- Obtain the names and types of the local variables and formal parameters from the routine's symbol table.

Allocating an Activation Record

```
TYPE arr = ARRAY[1..3] OF integer;
...
PROCEDURE proc(i, j : integer;
               VAR x, y : real;
               VAR a : arr;
               b : arr);
VAR
    k : integer;
    z : real;
```



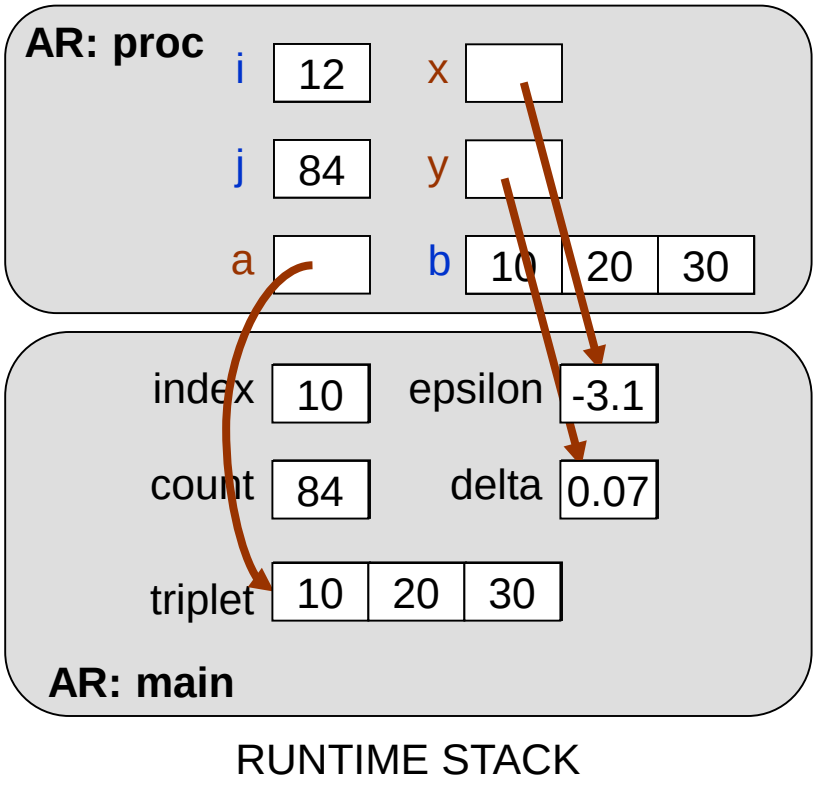
- Whenever we call a procedure or function:
  - Create an activation record.
  - Push the activation record onto the runtime stack.
  - Allocate the memory map of data cells based on the symbol table.

No more storing runtime values in the symbol table!

Passing Parameters During a Call

```
PROGRAM main;
TYPE
  arr = ARRAY[1..3] OF integer;
VAR
  index, count : integer;
  epsilon, delta : real;
  triplet : arr;

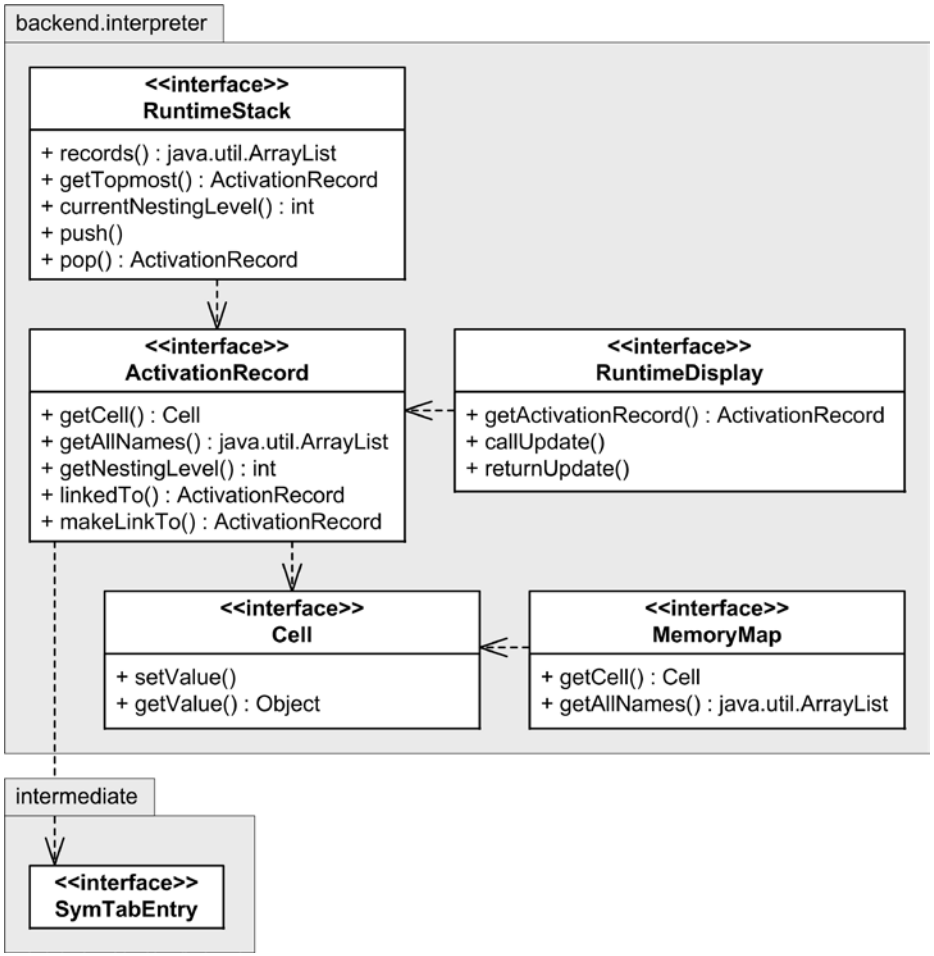
PROCEDURE proc(i, j : integer;
               VAR x, y : real;
               VAR a : arr;
               b : arr);
  ...
BEGIN {main}
  ...
  proc(index + 2, count, epsilon,
       delta, triplet, triplet);
END.
```



RUNTIME STACK

- Value parameters: A copy of the value is passed.
- VAR parameters: A reference to the actual parameter is passed.

Memory Management Interfaces



- Implementations:
  - Runtime stack: `ArrayList<ActivationRecord>`
  - Runtime display: `ArrayList<ActivationRecord>`
  - Memory map: `HashMap<String, Cell>`
- Class `MemoryFactory` creates:
  - runtime stack
  - runtime display
  - memory map
  - cell

Class **`RuntimeStackImpl`**

- In package **`backend.interpreter.memoryImpl`**
- Extends **`ArrayList<ActivationRecord>`**
- Methods
  - **`push(ActivationRecord ar)`**
    Push an activation record onto the runtime stack.
  - **`ActivationRecord pop()`**
    Pop off the top activation record.
  - **`ActivationRecord getTopmost (int nestingLevel)`**
    Return the topmost activation record at a given nesting level. (Uses the runtime display!)

Class **RuntimeDisplayImpl**

- In package **backend.interpreter.memoryImpl**
- Extends **ArrayList<ActivationRecord>**
- Methods
  - **ActivationRecord getActivationRecord (int nestingLevel)**
    Get the activation record at a given nesting level.
  - **callUpdate(int nestingLevel, ActivationRecord ar)**
    Update the display for a call to a routine at a given nesting level.
  - **returnUpdate(int nestingLevel)**
    Update the display for a return from a routine at a given nesting level.

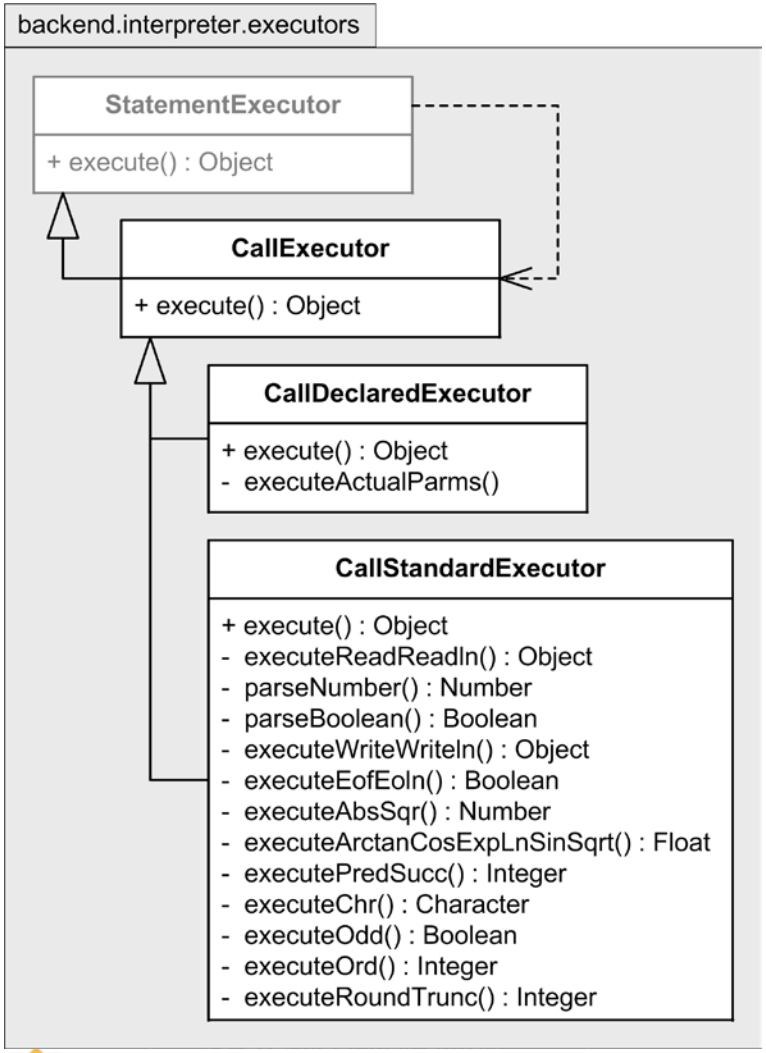
Class `MemoryMapImpl`

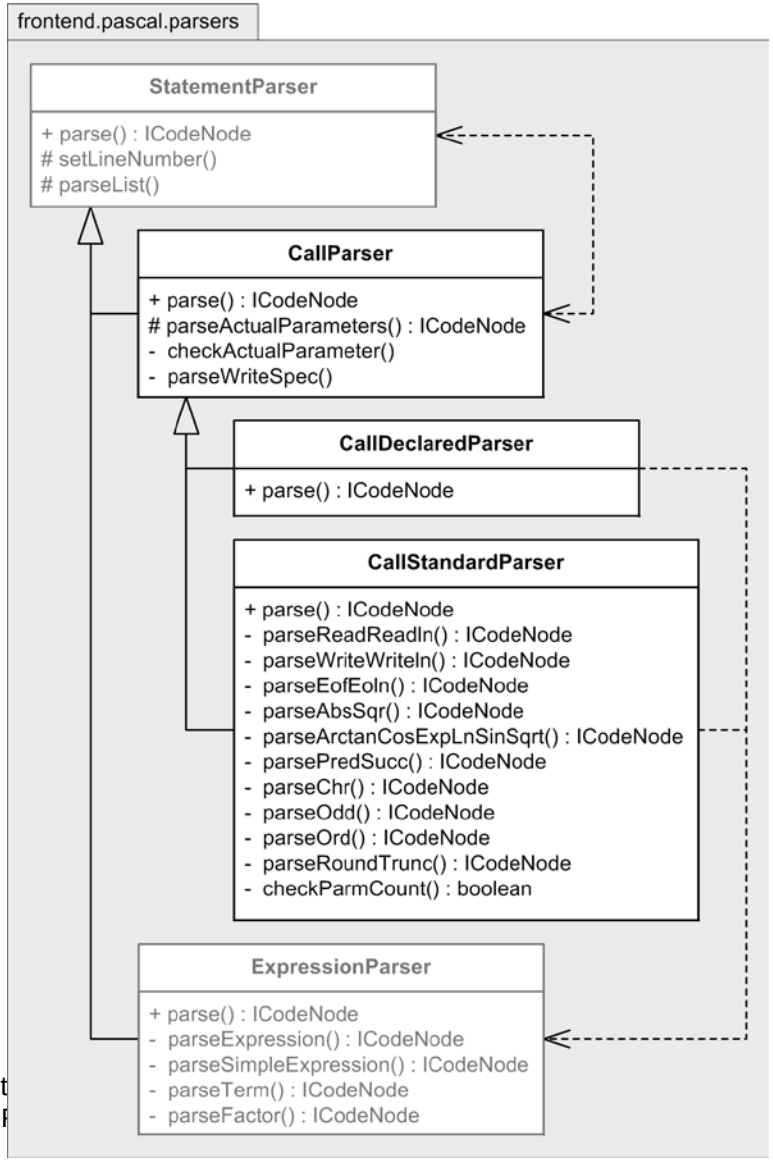
- In package **`backend.interpreter.memoryimpl`**
- Extends **`HashMap<String, Cell>`**
- Methods
  - **`MemoryMapImpl(SymTab symTab)`**
    Allocate the memory cells based on the names and types of the local variables and formal parameters in the symbol table.
  - **`Cell getCell(String name)`**
    Return the memory cell with the given name.
  - **`ArrayList<String> getAllNames()`**
    Return the list of all the names in this memory map.

Class `ActivationRecordImpl`

- In package `backend.interpreter.memoryimpl`
- Fields
  - `int nestingLevel`
  - `MemoryMap memoryMap`
    Values of the local variables and formal parameters
  - `ActivationRecord link`
    Link to the previous topmost activation record with the same nesting level in the runtime stack
- Method `Cell getCell(String name)`
  - Return a reference to a memory cell in the memory map that is keyed by the name of a local variable or formal parameter.

Executing Procedure and Function Calls





Class `CallDeclaredExecutor`

- Method **`execute()`**
  - Create a new activation record based on the called routine's symbol table.
  - Execute the actual parameter expressions.
  - Initialize the memory map of the new activation record.
    - The symbol table entry of the name of the called routine points to the routine's symbol table.
    - Copy values of actual parameters passed by value.
    - Set pointers to actual parameters passed by reference.

Class `CallDeclaredExecutor` *cont'd*

- Method `execute()` *cont'd*
  - Push the new activation record onto the runtime stack.
  - Access the root of the called routine's parse tree.
    - The symbol table entry of the name of the called routine points to the routine's parse tree.
  - Execute the routine.
  - Pop the activation record off the runtime stack.

Class `CallDeclaredExecutor`

- Method **`executeActualParms()`**
  - Obtain the formal parameter cell in the new activation record:

```
Cell formalCell = newAr.getCell(formalId.getName());
```

Class **`CallDeclaredExecutor`**

- Method **`executeActualParms()`** *cont'd*
  - Value parameter:

```
Object value =
       expressionExecutor.execute(actualNode);

assignmentExecutor.assignValue
                          (actualNode, formalId,
                           formalCell, formalType,
                           value, valueType);
```

Set a copy of the value of the actual parameter into the memory cell for the formal parameter.

Class **`CallDeclaredExecutor`**

- Method **`executeActualParms()`** *cont'd*
  - VAR (reference) parameter:

```
Cell actualCell=
    (Cell) ExpressionExecutor.executeVariable
                                        (actualNode);
formalCell.setValue(actualCell);
```

Set a reference to the actual parameter
into the memory cell for the formal parameter.

  - Method **`ExpressionExecutor.executeVariable()`** executes the parse tree for an actual parameter and returns the reference to the value.

Class `Cell`

- Since a memory cell can contain a value of any type or a reference, we implement it simply as a Java object.

```
package wci.backend.interpreter.memoryimpl;

public class CellImpl implements Cell
{
    private Object value = null;

    ...

    public void setValue(Object newValue)
    {
        value = newValue;
    }

    public Object getValue()
    {
        return value;
    }
}
```

Runtime Error Checking

- Range error
  - Assign a value to a variable with a subrange type.
  - Verify the value is within range
    - Not less than the minimum value and not greater than the maximum value.
  - Method **`StatementExecutor.checkRange()`**
- Division by zero error
  - Before executing a division operation, check that the divisor's value is not zero.

Pascal Interpreter

- Now we can execute entire Pascal programs!
  - Demo

Assignment #4: Complex Type

- Add a built-in complex data type to Pascal.
  - Add the type to the global symbol table.
  - Implement as a record type with real fields **re** and **im**.
- Declare complex numbers:

```
VAR
    x, y, z : complex;
```

- Assign values to them:

```
BEGIN
    z.re := 3.14;
    z.im := -8.2;
    ...
```

Assignment #4, *cont'd*

- Do complex arithmetic:

```
z := x + y;
```

- The backend executor does all the work of evaluating complex expressions. Use the following rules:
  - $(a + bi) + (c + di) = (a + c) + (b + d)i$
  - $(a + bi) - (c + di) = (a - c) + (b - d)i$
  - $(a + bi)(c + di) = (ac - bd) + (ad + bc)i$
  - $\frac{a+bi}{c+di} = \frac{(ac+bd)+(bc-ad)i}{c^2+d^2}$

Assignment #4, *cont'd*

- Start with the Java code from Chapter 12.
- Examine
  `wci.intermediate.symtabimpl.Predefined` to see how the built-in types like **`integer`** and **`real`** are defined.
- Examine
  `wci.frontend.pascal.parsers.RecordTypeParser`
  to see what information is entered into the symbol table for a **`record`** type.