Today's Topics

Previously

- S/SL program structure and operations

This Time

- Semantic mechanisms
- S/SL implementation

S/SL Semantic Mechanisms

Semantic Mechanisms

- For anything more than a simple parser, we need the ability to manipulate the values recognized by the parser, and to make decisions based on those stored values
- Semantic operations provide this ability
- Semantic operations are grouped into semantic mechanisms
- These are traditionally designed as abstract data types - that is, they provide operations on a particular conceptually single data structure (kind of like a class)
- The interface to the semantic routines is defined in S/SL, but no details of the implementation are visible at the S/SL level

S/SL Semantic Mechanisms

Semantic Mechanism Definitions

- Semantic mechanisms are specified in S/SL using a mechanism definition

```
type number:
   zero = 0;

mechanism Count:             % a stack of counters
   oCountPush(number)        % push a new counter
   oCountPop                 % discard top counter
   oCountIncrement           % add 1 to top counter
   oCountDecrement           % subtract 1 from top
   oCountChoose >> number;   % return the top value

mechanism TypeTable:
   oTypeEnterKind(typekinds)
   oTypeEnterSubscriptCount
     ...
   ;
```

S/SL Semantic Operations

Semantic Operations

- Semantic mechanisms can have two kinds of semantic operations, update (procedural) and choice (functional)
- Update operations are defined simply by listing their name in the mechanism definition

```
oCountPop
oCountIncrement
```

- Choice operation definitions additionally give the type the operation returns

```
oCountChoose >> Number
```

- Either kind may be defined to be parameterized by a single parameter of a given type

```
oCountPush(Number)
oCountGreaterThan(Number) >> boolean
```

S/SL Semantic Operations

Naming Semantic Operations

- By convention all semantic operations are named beginning with "o" (for "operation") followed by the name of the semantic mechanism they belong to

```
oCountPop                    % operations of the Count
oCountIncrement              % mechanism

oTypeChoose >> TypeKind      % an operation of the Type
                             % mechanism
```

- Semantic operations are invoked simply by using their name as an action in a rule

Semantic Operations - An Example

```
ArrayType:
   oTypeEnterKind(tyArray)
   '['
   oCountPush(zero)
   {
      @Expression '..' @Expression
      oCountIncrement
      [
        | ',':
        |*: >
      ]
   }
   ']'
   oTypeEnterSubscriptCount
   oCountPop
   @ArrayElementType;
```

```
 var x : array [1..4, 2..5] of Integer
              ^
```

A Complete S/SL Program

```
input:
   cLetter
   cDigit
   cBlank
   cPlus     '+'
   cMinus    '-'
   cIllegal;

output:
   pIdentifier
   pInteger
   pPlus
   pMinus;

error:
   eBadCharacter;

mechanism Buffer:
   oBufferSave;
```

```
rules

Scanner:
   @SkipBlanks
   [
      | cLetter:
        @ScanIdentifier
      | cDigit:
        @ScanInteger
      | '+':
        .pPlus
      | '-':
        .pMinus
   ];

SkipBlanks:
   {[
      | cBlank:
      | cIllegal:
         #eBadCharacter
      | *: >
   ]};
```

```
ScanIdentifier:
   oBufferSave
   {[
      | cLetter,cDigit:
         oBufferSave
      | *:
         >
   ]}
   .pIdentifier;

ScanInteger:
   oBufferSave
   {[
      | cDigit:
         oBufferSave
      | *:
         >
   ]}
   .pInteger;

end
```

S/SL Implementation

The S/SL Virtual Machine

- S/SL is a compiler generation tool - so not surprisingly, it is implemented in much the same way as a compiler
- S/SL is compiled (by a program written in S/SL!) to an abstract machine (byte code virtual machine) designed specifically for the S/SL language
- The machine is a simple stack based abstract machine - the instruction store (code memory) is represented as an array of integers
- There are 13 instructions, each of which is represented as an integer operation code

1. oJumpForward *label*
2. oJumpBack *label*
3. oInput *token*
4. oInputAny
5. oEmit *token*
6. oError *signal*
7. oInputChoice *table*
8. oCall *label*
9. oReturn
10. oSetResult *value*
11. oChoice *table*
12. oEndChoice
13. oSetParameter *value*

The S/SL Interpreter

JVM for S/SL

- S/SL bytecode tables are interpreted by a simple program called the S/SL walker, that simply emulates the S/SL machine

```
ReadTable();
processing = true;
SSLPointer = 0;

while(processing) {
    switch SSLTable[SSLPointer] {
        case oJumpForward:
            ... code for oJumpForward
        case oJumpBack:
            ... code for oJumpBack
        ...

        case oSetParameter:
            ... code for oSetParameter

        code for semantic operations
    }
}
```

S/SL Implementation - Instruction Store

Instruction Memory

- The instruction memory of the S/SL machine is represented as an array of integers (byte codes)
- We use the notation *index : value* to represent the array in the examples below

```
oJumpForward L9          123: 1
                         124: 55      L9 = 179

oJumpBack L1             172: 2
                         173: 23      L1 = 150

oInput '%'               201: 3
                         202: 15      token for % is 15

oInputAny                152: 4

oEmit foo                153: 5
                         154:135      foo = 135
```

S/SL Implementation - Call/Return

Rule Call and Return Implementation

- Rule call and return are straightforward

```
Foo:                          Foo:
    @Bar                          oCall Bar
    ;                             oReturn

Bar:                          Bar:
       ...                           ...
    ;                             oReturn
```

S/SL Implementation - Cycle and Exit

Loop Implementation

- Cycles are a little more interesting:

```
Foo:                    Foo:
    {                   L25:
        ...                     ...
      >                     oJumpForward L26
        ...                     ...
    }                       oJumpBack L25
                        L26:
    ;                       oReturn
```

S/SL Implementation - Choice Tables

Choice Implementation

- Choice tables used for input and semantic choices are implemented as an array of <value,address> pairs preceded a count of the number of pairs in the table

```
table:
    N
    value1  label1
    value2  label2
        ...
    valueN  labelN
    code for default
```

- For input choice tables, the values are input token values
- For semantic choices, the values are the type constant values
- The S/SL machine searches the N entries for a match - if none is found, execution continues at the end of the table (the default)
- If no default exists, the oEndChoice instruction is used to indicate it - if execution hits an oEndChoice, an error is caused

S/SL Implementation - Semantic Mechanisms

Extending the S/SL Machine

- Semantic mechanisms are implemented by extending the S/SL machine to have more operation codes
- Each semantic operation is implemented as a new operation code, and the statements to implement it are added to the S/SL table walker (by hand)
- Semantic operations can use two special "registers"

resultValue	holds the result of a choice rule or choice semantic operation
parameterValue	holds the parameter value given to a parameterized semantic operation

```
Foo >> Boolean:          Foo:
   >> true;                 oSetResult   1
                            oReturn

oCountPush(zero)         oSetParameter   0
                         oCountPush
```

S/SL Implementation - Example Translation

```
SkipBlanks:
  {
    [

      | cBlank:


      | cIllegal:
          #eBadChar










      | *:
          >


    ]
  }


  ;
```

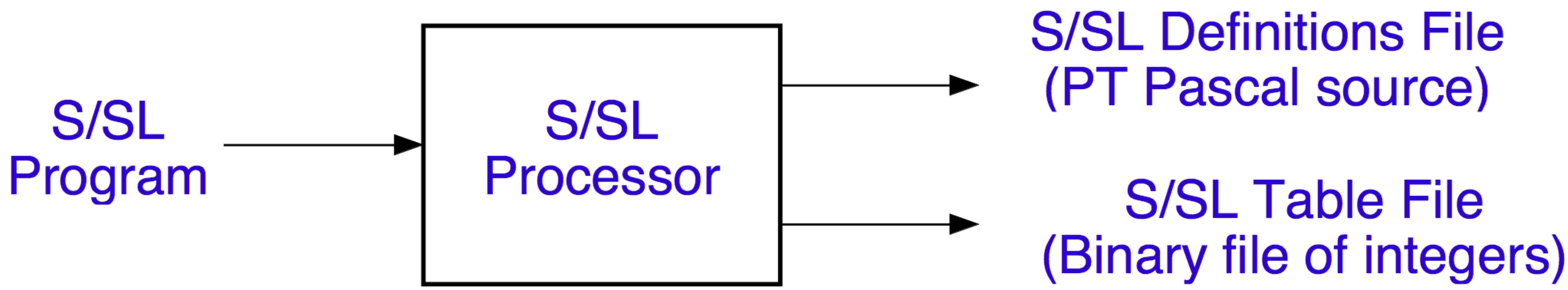
```
SkipBlanks:
L1:
      oInputChoice TBL      51: 7
                            52: 7
L2:
      oJumpForward L4       53: 1
                            54: 12
L3:
      oError eBadChar       55: 6
                            56: 10
      oJumpForward L4       57: 1
                            58: 8
TBL: 2                      59: 2
      cBlank L2             60: 2
                            61: 8
      cIllegal L3           62: 3
                            63: 8

      oJumpForward L5       64: 1
                            65: 3
L4:
      oJumpBack L1          66: 2
                            67: 16
L5:
      oReturn               68: 9
```

The S/SL Processor

Compiling S/SL to S/SL Bytecode

- The S/SL Processor is a program that compiles S/SL programs to bytecode for the S/SL machine

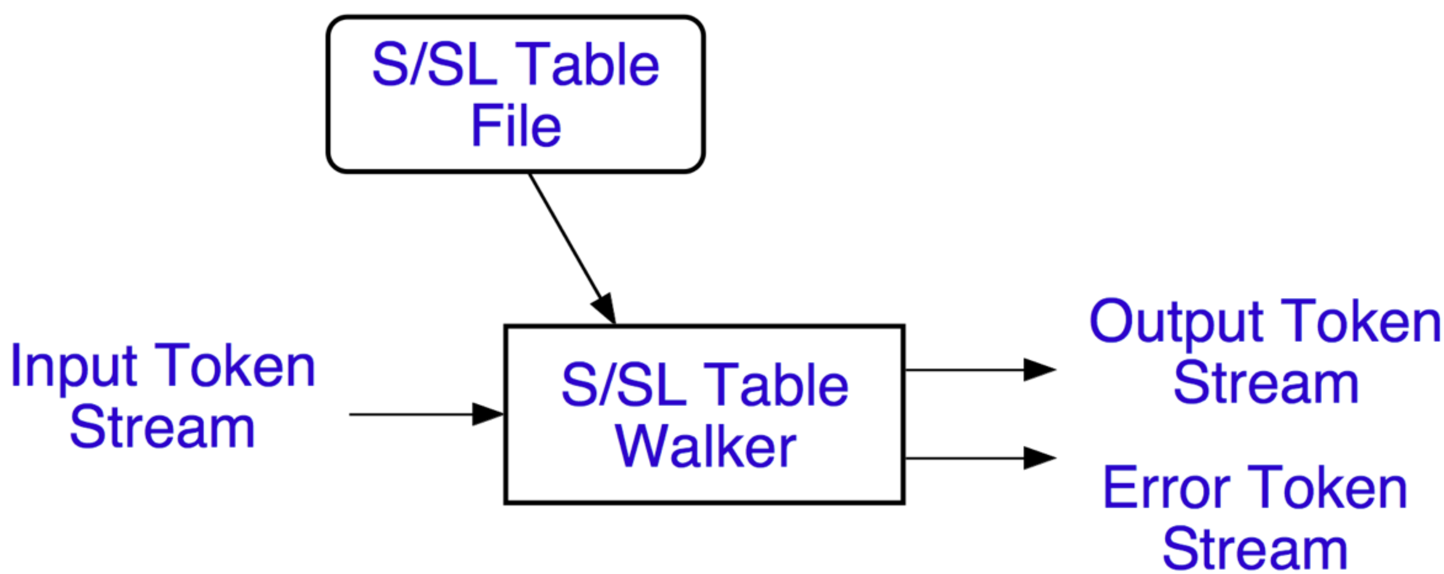


- The definitions file contains generated PT Pascal constant definitions that must be merged into the source of the S/SL "walker" (bytecode interpreter)
- The walker must also be customized with code to implement the semantic mechanisms (if any) used in the S/SL program, and then compiled to make a runnable walker
- The table file contains the S/SL bytecode to be read in and interpreted by the walker at run time

The S/SL Walker

Interpreting S/SL Bytecode

- The customized S/SL "table walker" then implements the S/SL machine (customized to the program)
- It reads the binary S/SL table file (bytecode) generated by the S/SL Processor and executes it operation by operation, simulating the S/SL machine



Summary

S/SL Implementation

- S/SL is a special purpose high level executable specification language specially designed for implementing compiler phases
- S/SL separately specifies the relationship between input stream and output stream (the important part of a compiler phase), while hiding internal data state in semantic mechanisms
- S/SL is compiled by the S/SL Processor into a compact byte code interpreted by the S/SL "walker", which executes it
- The walker is augmented with code to implement the semantic operations of the mechanisms used in the S/SL program

First Tutorial

- Tomorrow (Thursday) night, 6:30 pm, Botterell B139 - Don't miss it!

Next Week

- All about phase 1: Scanner/Screeners
- Mathematical underpinnings: Formal Specification of Languages
- Team contracts due, hand out Phase 1