Course Project

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We Will Implement A Simple Compiler

- Our goal in this project is to build a compiler for a simple programming language, called *MICRO*
- *MICRO* is popularly used for teaching students how to build compilers in many universities
- Our compiler will translate a *MICRO* program into a simple two-address assembly program, called *Tiny*

MICRO Language

- For the purpose of this course, we will use a modified version of *MICRO*
- *MICRO* syntax is a bit similar to C
- MICRO is case-sensitive
- Keywords are written using capital letters only
- Function “main” is where the execution starts
- Three data types are used: INT, FLOAT, and STRING
  - STRING variables are read-only and must be initialized when declared
  - INT and FLOAT variables can be read and written and are not initialized when declared

“Hello” Program in *MICRO*


```
PROGRAM hello
BEGIN
    STRING str := “Welcome to MICRO!” ;

    FUNCTION void main ( )
        WRITE ( str ) ;              -- print on the screen
    END

END
```

Tiny Assembly Code

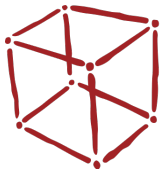
- The output of our compiler is *Tiny*: a two-address assembly code
- We will use a **simulator** to execute and test translated *Tiny* codes
- I will go into more details about *Tiny* later

Compilation is Done in Multiple Passes

- During the translation, compilers **pass** over the source code or the IR several times
- Each pass usually comprises a single task
  - For example, the first pass is scanning, next pass is parsing, next pass is symbol table generation, etc
- The output of each pass is the input of the next pass
- Multi-pass compilers are very popular
  - **We will use the multi-pass scheme in our project**
- Single-pass compilers (where everything is done in one pass) do exist but less commonly used

Coding Language is Java

- We will implement the compiler in Java
- Java is platform-independent
  - We need not worry about OS compatibility 
- Java is also known for being easy to learn, write, compile and debug
- Multiple nice IDEs that support Java are available



Coding Tips

- Do the design first, then write the code
- Take advantage of object-oriented programming
- Some of the good programming practices:
  - Keep the code simple
  - Use good naming scheme
  - Keep the code portable and extendable
  - Eliminate redundancy
  - Encapsulate what varies into classes

Project Steps

- Step0: forming teams
- Step1: implementing the scanner
- Step2: implementing the parser
- Step3: building the symbol table
- Step4: generating the IR
- Step5: generating *Tiny* code
- Step6 (not included for BSc): implementing live variables dataflow analysis
- Step7 (not included for BSc): implementing register allocation

Step 0: Forming Teams

- Each team should consist of 2 students
- You may ask other teams questions about Java or the IDE but not about the compiler design or code
- It is really common sense to tell what is cheating and what is not
- Team Registration link: TBD

Step1: Building The Scanner

- We will use ANTLR to automatically obtain the code of the scanner (isn't that great?!)
- ANTLR's input is a text file that specifies the regular expression of each token, as well as the language grammar
  - We will worry about the grammar in Step 2
- To complete step1, you need to learn
  - How to express regular expressions with ANTLR
  - How to use ANTLR tool to generate the scanner code
  - How to integrate the scanner code with your compiler code

Token Types in *MICRO*

- KEYWORD
- OPERATOR
- IDENTIFIER
- INTLITERAL, FLOATLITERAL, STRINGLITERAL
- COMMENT

Keywords in *MICRO*

PROGRAM	declare a program
BEGIN	Similar to an open bracket '{' in C
END	Similar to a closed bracket '}' in C
FUNCTION	declare a function
RETURN	Similar to return in C
READ	Read the input from the user
WRITE	Print on the screen
IF, ELSE, ENDIF	IF statement keywords
FOR, ENDFOR	FOR statement keywords
INT, VOID, STRING, FLOAT	Data type declarations

Operators in *MICRO*

:=	Assignment operator
+	Plus
-	Minus
*	Multiply
/	Divide
=	Test if equal
!=	Test if not equal
<	Test if smaller
>	Test if greater
<=	Test if less or equal
>=	Test if greater or equal
;	Same as C: a code statement must end with a semicolon
,	Same as C: separate parameters using a comma
(	Left parenthesis
)	Right parenthesis

Identifiers in *MICRO*

- An identifiers token will begin with a letter, followed by any number of letters and numbers
  - Letters can be small or capital
  - A number consists of characters 0, 1, …, 9
- Example on valid identifier names:

  N, m, STR, str, Str1, a100
- Example on non-valid identifier names:

  8N, STR!, 1

Literals in *MICRO*

- Three types of literals can be used:

1. INTLITERAL
   - Any integer number
2. FLOATLITERAL
   - Any real number with the format xxx.xxx or .xxx
   - integer and fraction parts can have any number of digits
3. STRINGLITERAL
   - any sequence of characters except ' " ' between ' " ' and ' " '
   - Valid string examples: "Hello!\n" and "****"

Comments in *MICRO*

- Any string that starts with "--" and lasts till the end of line
- The scanner must recognize comments but then ignore them (i.e., skip them)
- Valid comment examples:

  -- this is a comment

  -- $%#4-34455003-7354530

  --999--

Micro.g4

- Micro.g4 will be the input file of the ANTLR tool
- Below is skeleton of Micro.g4 code (your job is to finish it)

```
grammar Micro;

KEYWORD:        ……

OPERATOR:       ……

IDENTIFIER:     ……

INTLITERAL:     ……

FLOATLITERAL:       ……

STRINGLITERAL:      ……

COMMENT:        ……

WS : [ \t\r\n]+ -> skip ;     // skip spaces, tabs, newlines
```

Refer to the ANTLR v4 reference book to learn how write regular expressions with ANTLR

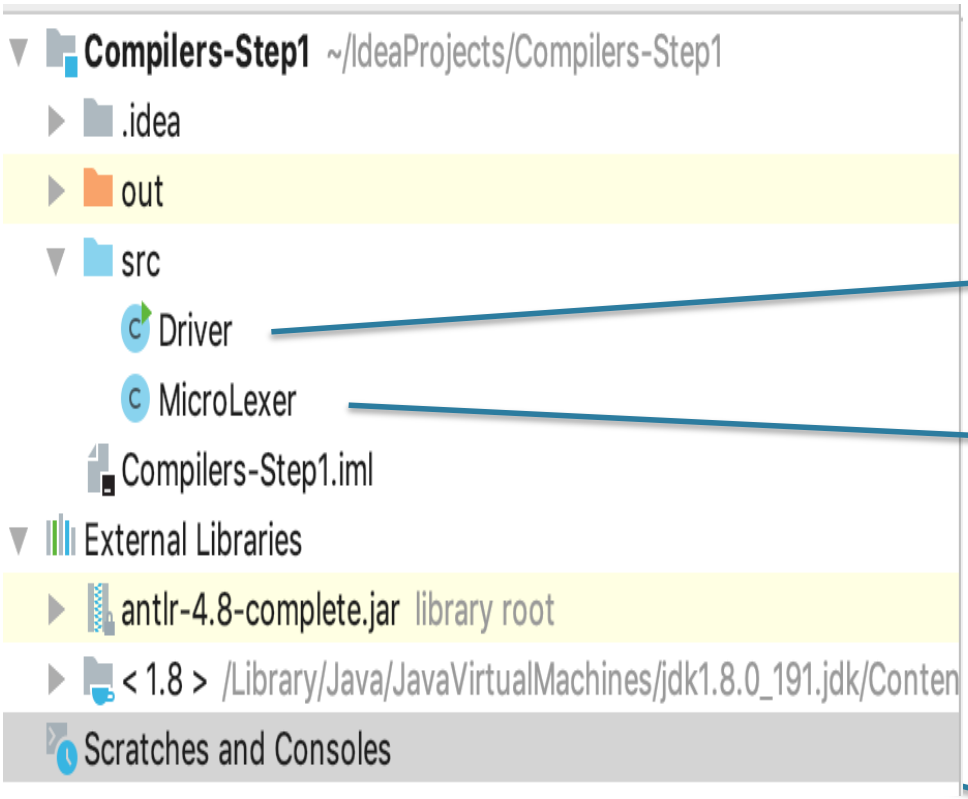
Using ANTLR Tool

- Download ANTLR: https://www.antlr.org/download/antlr-4.13.1-complete.jar
- Use the following command

```
java –jar antlr-4.13.1-complete.jar Micro.g4
```

- Scanner source code is then found in MicroLexer.java
- To use the scanner, simply integrate the scanner source code files with your code

Example: Integrating Scanner Code With Eclipse Project



This is the test file

add scanner class
to the project

Do not forget to add
ANTLR to the build path

Driver.java


```java
// import antlr
import org.antlr.v4.runtime.ANTLRInputStream;

import java.io.FileInputStream;
import java.io.InputStream;
public class Driver {
    public static void main(String[] args) throws Exception{
        // read input MICRO code
        InputStream is=null;
        try{
            String inputFile;
            inputFile = args[0];
            is = new FileInputStream(inputFile);
        }
        catch ( Exception e){
            System.out.println("You must specify an input file");
            System.exit( status: 0);
        }

        ANTLRInputStream input = new ANTLRInputStream(is);
        MicroLexer lexer = new MicroLexer(input);

        // add code here to print each token's type and value

    }
}
```

This code will invoke the lexer automatically

Step 1 Output

- Your code should read an input *MICRO* code, scan it, and then produce an output file that shows each token's type and value
- I uploaded a set of input *MICRO* code examples on the course website
- I also uploaded the expected output for each input code example
- Due: TBD