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6CCS3CFL-CW3

Q1

Grammer:

$$Stmts ::= Stmt; Stmts \mid Stmt$$
$$Block ::= \{Stmts\} | Stmt$$

$$AExp ::= Te + AExp \mid Te - AExp \mid Te$$
$$Te ::= Fa * Te \mid Fa \, / \, Te \mid Fa \,\%\, Te \mid Fa$$
$$Fa ::= (AExp) \mid num \mid id$$

$$\begin{aligned} Stmt := \ & skip | \\ & id := \ Aexp | \\ & write\ (id) \mid \\ & write\ (string) \mid \\ & write\ id \mid \\ & write\ string \mid \\ & read\ (id) \mid \\ & read\ id \mid \\ & if\ BExp\ then\ Block\ else\ Block \mid \\ & while\ BExp\ do\ Block \end{aligned}$$

Type equation here.

$$\begin{aligned} BExp := \ & AExp == \ AExp | \\ & AExp \, != AExp | \\ & AExp < AExp | \\ & AExp \leq AExp | \\ & AExp > AExp | \\ & AExp \geq AExp | \\ & (BExp\ ) \,\&\&\, BExp | \\ & (BExp) \mid\mid BExp | \\ & true | \\ & false | \\ & (BExp) \end{aligned}$$

For making my parser recognise tokens, I had to change the implementation of a few essential functions.

I introduced a few new implicit definitions which correspond to
`Parser[List[Token], Token]`
And also introduced some atomic parsers for some specific tokens.

Boolen Expressions

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```scala
// boolean expressions with some simple nesting
lazy val BExp: Parser[List[Token], BExp] =
   (AExp ~ T_OP("==") ~ AExp).map[BExp]{ case x ~ _ ~ z => Bop("==", x, z) } ||
   (AExp ~ T_OP("!=") ~ AExp).map[BExp]{ case x ~ _ ~ z => Bop("!=", x, z) } ||
   (AExp ~ T_OP("<") ~ AExp).map[BExp]{ case x ~ _ ~ z => Bop("<", x, z) } ||
   (AExp ~ T_OP(">") ~ AExp).map[BExp]{ case x ~ _ ~ z => Bop(">", x, z) } ||
   (AExp ~ T_OP(">=") ~ AExp).map[BExp]{ case x ~ _ ~ z => Bop(">=", x, z)} ||
   (AExp ~ T_OP("<=") ~ AExp).map[BExp]{ case x ~ _ ~ z => Bop("<=", x, z)} ||
   (T_LPAREN_N ~ BExp ~ T_RPAREN_N ~ T_OP("&&") ~ BExp).map[BExp]{ case _ ~ y ~ _ ~ _ ~ v => And(y, v) } ||
   (T_LPAREN_N ~ BExp ~ T_RPAREN_N ~ T_OP("||") ~ BExp).map[BExp]{ case _ ~ y ~ _ ~ _ ~ v => Or(y, v) } ||
   (T_KWD("true").map[BExp]{ _ => True }) ||
   (T_KWD("false").map[BExp]{ _ => False }) ||
   (T_LPAREN_N ~ BExp ~ T_RPAREN_N).map[BExp]{ case _ ~ x ~ _ => x }
```

Arithmetic Expressions

```scala
// arithmetic expressions
lazy val AExp: Parser[List[Token], AExp] =
    (Te ~ T_OP("+") ~ AExp).map[AExp]{ case x ~ _ ~ z => Aop("+", x, z) } ||
    (Te ~ T_OP("-") ~ AExp).map[AExp]{ case x ~ _ ~ z => Aop("-", x, z) } ||
    Te

lazy val Te: Parser[List[Token], AExp] =
    (Fa ~ T_OP("*") ~ Te).map[AExp]{ case x ~ _ ~ z => Aop("*", x, z) } ||
    (Fa ~ T_OP("/") ~ Te).map[AExp]{ case x ~ _ ~ z => Aop("/", x, z) } ||
    (Fa ~ T_OP("%") ~ Te).map[AExp]{ case x ~ _ ~ z => Aop("%", x, z) } ||
    Fa

lazy val Fa: Parser[List[Token], AExp] =
    (T_LPAREN_N ~ AExp ~ T_RPAREN_N).map{ case _ ~ y ~ _ => y } ||
    IdParserToken.map(Var) ||
    NumParserToken.map(Num)
```

Single Statements

Had to introduce extra cases of write since there were various different ways it was implemented in test programs.

```scala
// a single statement
/* we need 4 types of writes here
 write id
 write "string"
 write (id)
 write ("string")
*/
lazy val Stmt: Parser[List[Token], Stmt] =
  ((T_KWD("skip").map[Stmt]{_ => Skip }) ||
   (IdParserToken ~ T_OP(":=") ~ AExp).map[Stmt]{ case x ~ _ ~ z => Assign(x, z) } ||
   (T_KWD("write") ~ T_LPAREN_N ~ IdParserToken ~ T_RPAREN_N).map[Stmt]{ case _ ~ y ~ _ => WriteVar(y) } ||
   (T_KWD("write") ~ StrParserToken).map[Stmt]{ case _ ~ y => WriteStr(y) } ||
   (T_KWD("write") ~ IdParserToken).map[Stmt]{ case _~ y => WriteVar(y)} ||
   (T_KWD("write") ~ T_LPAREN_N ~ StrParserToken ~ T_RPAREN_N).map[Stmt]{ case _ ~ _ ~ y ~ _ => WriteStr(y) } ||
   (T_KWD("read") ~ IdParserToken).map[Stmt]{ case _ ~ y => Read(y) } ||
   (T_KWD("if") ~ BExp ~ T_KWD("then") ~ Block ~ T_KWD("else") ~ Block)
   .map[Stmt]{ case _ ~ y ~ _ ~ u ~ _ ~ w => If(y, u, w) } ||
   (T_KWD("while") ~ BExp ~ T_KWD("do") ~ Block).map[Stmt]{ case _ ~ y ~ _ ~ w => While(y, w) })
```

Compound Statements

```scala
// statements
lazy val Stmts: Parser[List[Token], Block] =
  (Stmt ~ T_SEMI ~ Stmts).map[Block]{ case x ~ _ ~ z => x :: z } ||
  (Stmt.map[Block]{ s => List(s) })
```

Blocks

```scala
// blocks (enclosed in curly braces)
lazy val Block: Parser[List[Token], Block] =
  ((T_LPAREN_C ~ Stmts ~ T_RPAREN_C).map{ case _ ~ y ~ _ => y } ||
   (Stmt.map(s => List(s))))
```

Q2

Output of running the respective programs:

__________Fib __________

HashSet(List(WriteStr("Fib"), Read(n), Assign(minus1,Num(0)), Assign(minus2,Num(1)), While(Bop(>,Var(n),Num(0)),List(Assign(temp,Var(minus2)), Assign(minus2,Aop(+,Var(minus1),Var(minus2))), Assign(minus1,Var(temp)), Assign(n,Aop(-,Var(n),Num(1))))), WriteStr("Result"), WriteVar(minus2)))

__________Loops __________

HashSet(List(Assign(start,Num(100)), Assign(x,Var(start)), Assign(y,Var(start)), Assign(z,Var(start)), While(Bop(<,Num(0),Var(x)),List(While(Bop(<,Num(0),Var(y)),List(While(Bop(<,Num(0),Var(z)),List(Assign(z,Aop(-,Var(z),Num(1))))), Assign(z,Var(start)), Assign(y,Aop(-,Var(y),Num(1))))), Assign(y,Var(start)), Assign(x,Aop(-,Var(x),Num(1)))))))

__________Primes __________

Set(List(Assign(end,Num(100)), Assign(n,Num(2)), While(Bop(<,Var(n),Var(end)),List(Assign(f,Num(2)), Assign(tmp,Num(0)), While(And(Bop(<,Var(f),Aop(+,Aop(/,Var(n),Num(2)),Num(1))),Bop(==,Var(tmp),Num(0))),List(If(Bop(==,Aop(*,Aop(/,Var(n),Var(f)),Var(f)),Var(n)),List(Assign(tmp,Num(1))),List(Skip)), Assign(f,Aop(+,Var(f),Num(1))))), If(Bop(==,Var(tmp),Num(0)),List(WriteVar(n)),List(Skip)), Assign(n,Aop(+,Var(n),Num(1)))))))

__________Collatz __________

Set(List(Assign(bnd,Num(1)), While(Bop(<,Var(bnd),Num(101)),List(WriteVar(bnd), WriteStr(": "), Assign(n,Var(bnd)), Assign(cnt,Num(0)), While(Bop(>,Var(n),Num(1)),List(WriteVar(n), WriteStr(","), If(Bop(==,Aop(%,Var(n),Num(2)),Num(0)),List(Assign(n,Aop(/,Var(n),Num(2)))),List(Assign(n,Aop(+,Aop(*,Num(3),Var(n)),Num(1))))), Assign(cnt,Aop(+,Var(cnt),Num(1))))), WriteStr(" => "), WriteVar(cnt), WriteStr("\n"), Assign(bnd,Aop(+,Var(bnd),Num(1)))))))

Output for (**if** (a **<** b) **then skip else** a **:=** a * b + 1)

Set(List(If(Bop(<,Var(a),Var(b)),List(Skip),List(Assign(a,Aop(+,Aop(*,Var(a),Var(b)),Num(1)))))))

Parse Tree for (**if** (a **<** b) **then skip else** a **:=** a * b + 1) is denoted below.

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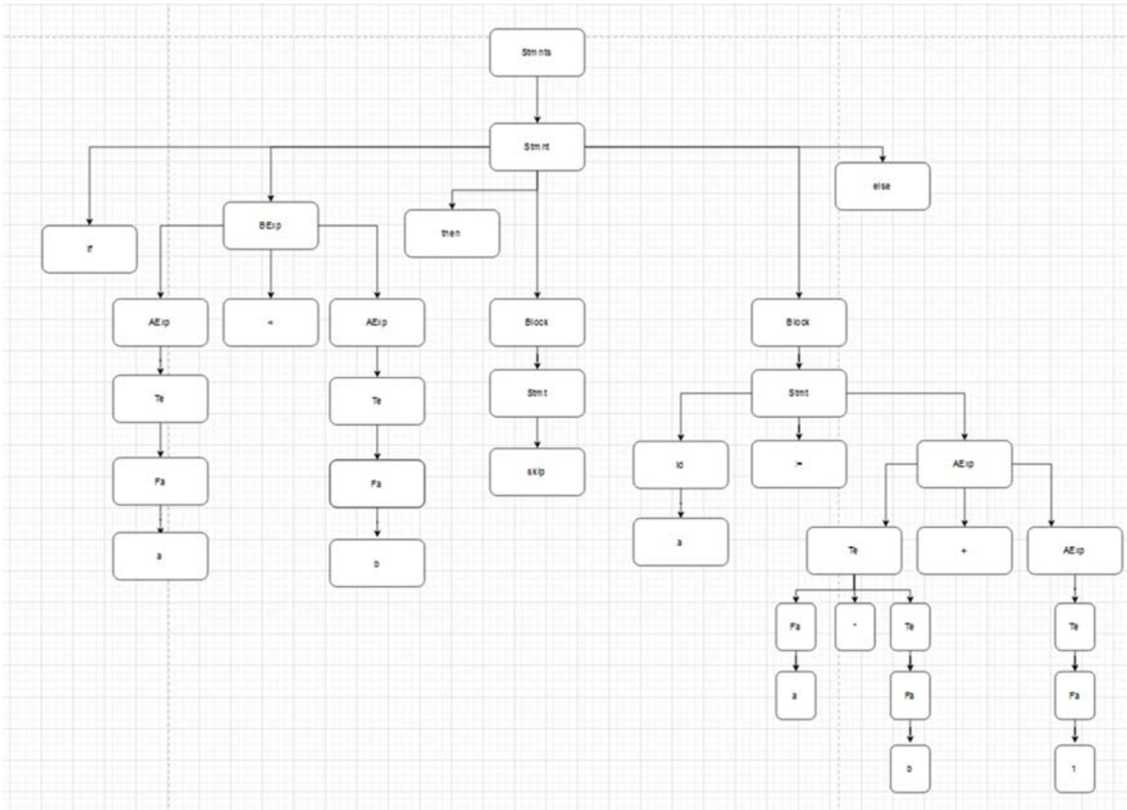
Stmnts
Stmt
if
BExp
then
else
AExp
<
AExp
Block
Block
Te
Te
Stmt
Stmt
Fa
Fa
skip
id
:=
AExp
a
b
a
Te
+
AExp
Fa
*
Te
Te
a
Fa
Fa
b
1

Q3

The Time measurements are outlined below.

1. **Fibonacci**

```
"Fib"
Waiting for User Input....
5
"Result"
8
Code Run Time: 2.3012644 s
```

2. **Three Nested Loops**

```
Loop Program - start: 100
Code Run Time: 0.4200543 s

Loop Program - start: 500
Code Run Time: 56.8611486 s

Loop Program - start: 800
Code Run Time: 199.663897 s
```

Started off with 100 which took less than half a second.
Then 500 took 1 minute to execute and lastly having a start value of 800 took just a little more than 3 minutes.

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3. Factors

```
2
3
5
7
11
13
17
19
23
29
31
37
41
43
47
53
59
61
67
71
73
79
83
89
97
Code Run Time: 4.2165406 s
```

4. Collatz

There were variations in the time it took to run this.

If the implementation of **WriteVar** and **WriteStr** had println, then the taken was significantly larger.

Whereas if the implementation only had print, then the time was lesser.

```
88","244","122","61","184","92","46","23","70","35","10
","49","148","74","37","112","56","28","14","7","22","1
99": "99","298","149","448","224","112","56","28","14","
 => "25"\n"100": "100","50","25","76","38","19","58","2
4","2","" => "25"\n"Code Run Time: 0.4592558 s
```

The above is with print and the one below is with println.

```
2
","
" => "
25
"\n"
Code Run Time: 3.5526806 s
```