C Programming Tools: Part 5

Building Lexers and Parsers (cont)

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- The handout and tarball are available on materials and at:

  `http://www.doc.ic.ac.uk/~dcw/c-tools-2021/lecture5/`

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- For example:

```
double :: Int -> Int
double x = x*2
abs x | x>0  = x
      | x==0 = 0
      | 0>x  = 0-x
fact x | x==1 = 1
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- In a break with strict Haskell-syntax, we'll decide that brackets on function calls like `abs(10)` are compulsory. Why? Because the lack of brackets confuses me:-)

- At the lexical level, we add the following new regex/action pairs to our Lex input file lexer.l - keeping all the integer expression rules unchanged:

```
Int                     return INTTYPE;
True                    return TRUEV;
::                      return COLONCOLON;
->                      return IMPLIES;
==                      return EQ;
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- The Abstract Syntax of THS, in types.in, is more complex:

```
arithop   =  plus or minus or times or divide or mod;
expr      =  num( int n )
          or id( string s )
          or binop( expr l, arithop op, expr r )
          or call( string s, expr e );
boolop    =  eq or ne or gt;
bexpr     =  truev or binop( expr l, boolop op, expr r );
guard     =  pair( bexpr cond, expr e );
guardlist =  nil or cons( guard hd, guardlist tl );
fbody     =  one( expr e ) or many( guardlist l );
fdefn     =  triple( string fname, string param, fbody b );
flist     =  nil or cons( fdefn hd, flist tl );
program   =  pair( flist l, expr e );
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        int       n;    char      *s;
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- Our token lists are bigger than before:

```
%token COLONCOLON IMPLIES EQ GT NE TRUEV PLUS MINUS MUL DIV MOD OPEN
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- Our parse rule type association list is also bigger:

```
%type <e>  factor term expr
%type <b>  bexpr
%type <g>  guard
%type <gl> guards
%type <f>  fdefinition
%type <fl> fdefns
```

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- The rest of the parser.y lists the grammatical parse rules that define THS, plus the corresponding tree-building actions to take when the rules match:

```
%%
program      : fdefns expr           { ast = program_pair( $1, $2 ); }
             ;
fdefns       : /* empty */           { $$ = flist_nil(); }
             | fdefns ftypedefn      { $$ = $1; /* ignore type defns */ }
             | fdefns fdefinition    { $$ = flist_cons( $2, $1 ); }
             ;
ftypedefn    : IDENT COLONCOLON INTTYPE IMPLIES INTTYPE { free_string( $1 ); }
             ;
fdefinition  : IDENT IDENT IS expr   { $$ = fdefn_triple( $1, $2, fbody_one($4) ); }
             | IDENT IDENT guards    { $$ = fdefn_triple( $1, $2, fbody_many($3) ); }
             ;
guards       : guard                 { $$ = guardlist_cons($1, guardlist_nil()); }
             | guards guard          { $$ = guardlist_push( $1, $2 ); }
             ;
guard        : GUARD bexpr IS expr   { $$ = guard_pair( $2, $4 ); }
             ;
bexpr        : expr EQ expr          { $$ = mkequals( $1, $3 ); }
             | expr NE expr          { $$ = mknotequals( $1, $3 ); }
             | expr GT expr          { $$ = mkgreaterthan( $1, $3 ); }
             | TRUEV                 { $$ = bexpr_truev(); }
             ;
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- Having built a new abstract guard, and associated it with the successful match of the guard parse rule, parsing continues trying to parse a non-empty sequence of guards, in which we have either a single guard, or some guards followed by one more guard:

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guards      : guard                    { $$ = guardlist_cons($1, guardlist_nil()); }
            | guards guard             { $$ = ?????( $1, $2 ); }
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- When the guards guard rule matches, we want our action to build a guard list with the guards *in the order they were encountered* in the THS input file.

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- But now, the action I write is `$$ = guardlist_push($1,$2)`. This function was manually written (you'll find it in the prelude section of types.in) and modifies the existing guardlist, finding the last node and adding the new guard on the end.

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- Finally, turning to the start rule, program:

```
program       :  fdefns expr             { ast = program_pair( $1, $2 ); }
              ;
```

When this rule matches the entire input, the action is invoked with the final function list in $1, and the main expression in $2, both get incorporated into a program_pair(), which is assigned to program ast.

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- Compile and link by typing make. We end up with a THS parser and treebuilder ths1, in which we only write about 430 lines of code. Give it a try!

- 02.ths-semanticchecker adds semantic checking - in THS, this means checking that we define every function we call, and also that every use of an identifier inside an (integer or boolean) expression is either a predefined named constant in consthash, or the current function's parameter. In other languages, we'd have to perform other semantic checks - for example the number and types of actual parameters to each called function.

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  - For simplicity, we perform the identifier in a factor checks inside parser.y, via a new check_id() function. There's always a fine line between parse checks and semantic checks.
- After a successful parse, the semantic checker iterates through the callset checking that each called function is present in the funchash.

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- We write C functions to:
  - Evaluate an integer expression in the current environment.
  - Evaluate a boolean expression in the current environment.
  - Select which guard in a guardlist is true and then evaluate it's corresponding integer expression, all in the current environment.
  - Handle a function call (possibly recursive).

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- Note that we also have to trap runtime errors such as division by zero and what happens if no guard evaluates to true.

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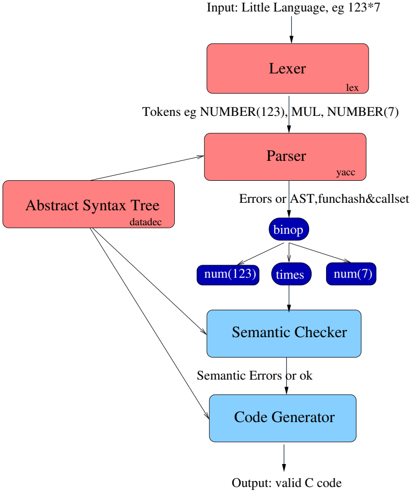

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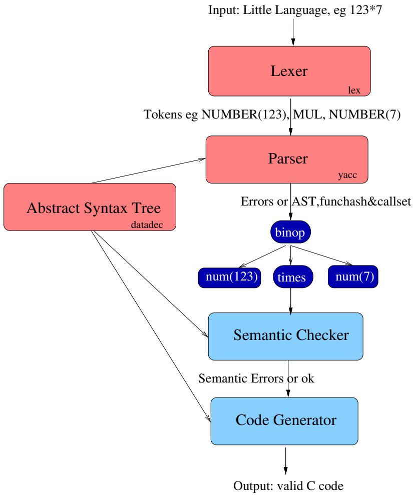

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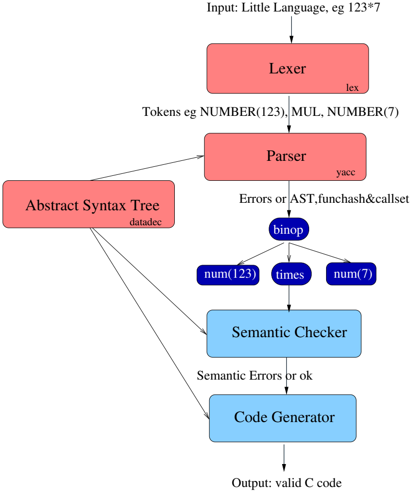

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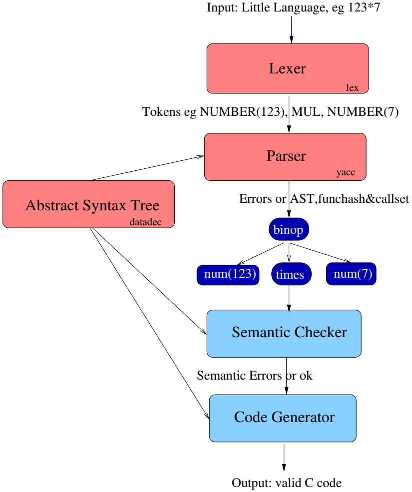

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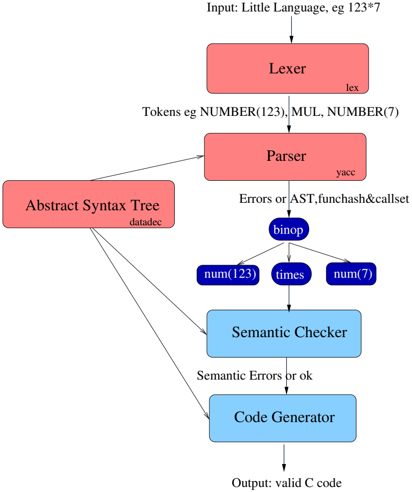

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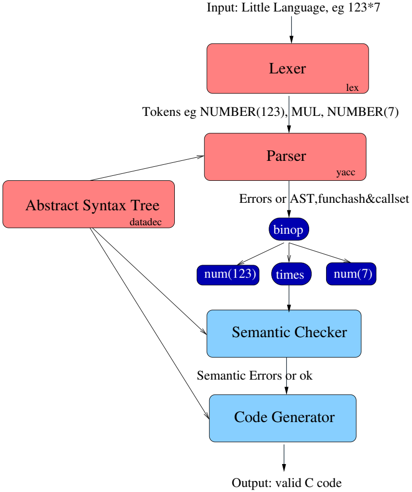

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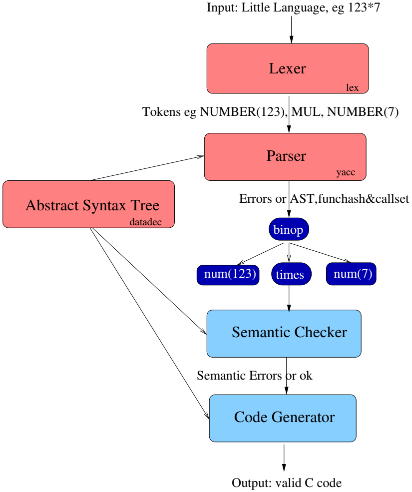

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- So, Yacc and Lex and Datadec are a scalable way of building translators for little languages, vital tools for your toolbox.
- In the tarball, left for you to explore, there's an extended version of THS - that I call BHS (for "Bigger Haskell Subset") that allows functions to have multiple parameters - all still integer.

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- Having defined the syntax of the new feature, we define it's semantics via a precise description of how to translate it back to standard C.

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- Thus, C with directives comes in, standard C goes out.

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- See interprete.cpm (found in the `interprete-eg` subdir) for a bigger example - the THS interpreter rewritten using the lovely new syntax.
- BTW, cpm reads information about types, shapes, and their parameters from datadec in a particularly sneaky fashion, which I'm very proud of.

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Ok, that's quite enough parsing. Let's sum up what I've been trying to say in these lectures - the Programming Tools philosophy:

- Follow 100,000 years of human history by tool-using and tool-making. Build yourself a powerful toolkit. Choose tools you like; become expert in each.
- When necessary, build tools yourself to solve problems that irritate you. Be strong! Tools often save you much more time than they cost you to make.
- Text manipulation languages are fantastic timesavers. Perl is especially good - known as The Swiss Army Chainsaw by SysAdmins. I used to run a Perl course, see `http://www.doc.ic.ac.uk/~dcw/perl2014/`
- I also write an occasional series of Practical (Pragmatic?) Software Development articles: `http://www.doc.ic.ac.uk/~dcw/PSD/`
- Read The Pragmatic Programmer. Then read it again!
- Most importantly: enjoy your C programming! Build your toolkit - and let me know if you build any particularly cool tools!