Building your own C Toolkit: Part 2

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- Last week, we introduced the idea of building a C programming toolkit, and covered the following tools or techniques:
  - Programmer's Editors.
  - Automatic Compilation: Make.
  - Automatic Ruthless Testing.
  - Debugging: gdb.
  - Generating prototypes automatically: proto.
  - Fixing memory leaks: libmem.
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  - Parser and Lexer Generator tools: yacc and lex.
- As last week, there's a tarball of examples associated with this lecture. Both lectures' slides and tarballs are available on CATE and at: `http://www.doc.ic.ac.uk/~dcw/c-tools/`

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  - Run `./iterate 10000`, which runs a bit slower than normal (because profiling slows it down a bit), producing a binary profiling file called gmon.out.
  - The tool gprof then analyzes the executable and the data file, producing a report showing the top 10 functions (across all their calls) sorted by percentage of total runtime. Run:
    `gprof ./iterate gmon.out > profile.orig`

- head profile.orig shows results like:

```
  %     cumul    self                 self   total
time   seconds  seconds    calls   us/call  us/call name
38.71    3.37    3.37      20000   168.37   206.96 hashFree
22.92    5.36    1.99      10000   199.44   289.14 hashCopy
11.29    6.34    0.98      10000    98.22    98.22 hashCreate
10.31    7.24    0.90  325330000    0.00     0.00 copy_tree
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- We can double the speed of iterate by adding if(the_tree != NULL) conditions on tree calls in hashFree, hashCopy and others.
- We might also consider shrinking the size of the array of trees to some smaller prime number - or, more radically, adding code to dynamically resize the array (and rehash all the keys) when the hash gets full.

- Principle: It's often an excellent idea to import cool features from other languages.
- For example, Perl teaches us the importance of hashes (aka Java dictionaries) - (key,value) storage implemented using hash tables. We've already seen a hash module bring this ability to C.

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- I looked around, couldn't find anything anywhere. Noone seemed to have ever suggested that such a tool could be useful!
- Decision time: do I abandon my brilliant idea, or write the tool?

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- In 04.datadec-eg you'll find an input file types.in containing:

```
TYPE {
       intlist =  nil or cons( int first, intlist next );
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- ... modify types.in - suppose you realise that an idtree node needs to store an id as well as the trees. Change the type defn, rerun datadec. Now the `idtree_node()` constructor takes 3 arguments!

- Let's look inside datatypes.h, to find what idtree functions datadec generates. First we find two *constructors*:

```
extern idtree idtree_leaf( string );
extern idtree idtree_node( idtree, idtree );
```

- Then we find a function telling you whether a tree is a leaf or a node:

```
extern kind_of_idtree idtree_kind( idtree );
```

  Using the enumerated type:

```
typedef enum { idtree_is_leaf, idtree_is_node } kind_of_idtree;
```

- Then two deconstructor functions which, given a tree of the appropriate shape, breaks it into it's constituent pieces:

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extern void get_idtree_leaf( idtree, string * );
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- I recommend the following: while experimenting with types.in, forget free()ing. When your recursive types have become stable, you should write the tree-traversing void free_TYPE(TYPE t) functions yourself. Add them to the GLOBAL section (after @@) in types.in - man datadec for more details.

- Looking in testidtree.c, we build two leaves, and then test that we can break them apart again:

```
idtree t1 = idtree_leaf( "absolutely" );
testleaf( t1, "absolutely", "ab" );
idtree t2 = idtree_leaf( "fabulous" );
testleaf( t2, "fabulous", "fab" );
```

- testleaf(t, expected, treename) tests that t is a leaf with the expected id, treename is a symbolic name for the tree:

```
void testleaf( idtree t, char *expected, char *treename )
{
  char label[1024];
  sprintf( label, "isnode(%s)", treename );
  inteqtest( idtree_kind(t), idtree_is_leaf, label );
  string id;
  get_idtree_leaf( t, &id );
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- Next, testidtree.c constructs a node from our two leaves, and tests that we can break it apart correctly:

```
idtree t = idtree_node( t1, t2 );
inteqtest( idtree_kind(t), idtree_is_node,
           "isnode((ab,fab))" );
idtree l, r;
get_idtree_node( t, &l, &r );
testleaf( l, "absolutely", "left((ab,fab))" );
testleaf( r, "fabulous", "right((ab,fab))" );
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    - anything else you find useful (.ini file parsers? test frameworks?)
- The C standard library fails to provide any of the following (C++ provides the Standard Template Library): So build them yourself as and when you need them, and reuse them at every opportunity, to raise C to a higher level!
- Reuse can be done without object orientation, it's not hard!

- We often find ourselves writing hundreds of repetitive “pattern instances”, differing only in small details, eg:

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int minus( int a, int b ) { return (a-b); }
int times( int a, int b ) { return (a*b); }
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- Specify input format (as a little language) and corresponding output:

```
INPUT:
  line 1: typename T eg. int
  foreach line>1: F, Op pairs

OUTPUT:
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int plus( int a, int b ) { return (a+b); }
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- All that varies from line to line is (funcname,operator), plus perhaps the type 'int' is also a parameter?
- Why not generate them automatically using an ad-hoc tool, scaffolding that you build in 30 minutes or less, use a few times, then discard?
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perl -nle 'if($.==1){$t=$_;next} ($f,$op)=split(/,/);...
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- Even if we write this in C, might take about 30 minutes using low-level string manipulation, or 10-15 minutes using standard library function strtok(). See 05.tiny-tool/README for details.

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- Specify the input tokens as regular expressions:

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[0-9]+                  return NUMBER;
\+                      return PLUS;
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- See lexer.l for the full lex input file, containing the above rules and some prelude. This file can be turned into C code via: lex -o lexer.c lexer.l.

- These tokens can be combined to form expressions using the following BNF-style grammar rules (in yacc-format):

```
%token PLUS MINUS MUL DIV MOD OPEN CLOSE TOKERR
%token NUMBER

%start oneexpr
%%
oneexpr       :  expr
              ;
expr          : expr PLUS term
              | expr MINUS term
              | term
              ;
term          : term MUL factor
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factor        : NUMBER
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- parser.y contains these rules plus some yacc-specific prelude, including a short main program that calls the parser. This can be turned into C code (parser.c and parser.h) via: yacc -vd -o parser.c parser.y

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oneexpr      : expr             { expr_result = $1; }
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expr         : expr PLUS term   { $$ = $1 + $3; }
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- After make we have expr2, an expression calculator. Play with it.

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factor      : NUMBER          { $$ = expr_num($1); }
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- Most importantly: enjoy your C programming! Build your toolkit - and let me know if you write any particularly cool tools!
- Finally, scripting languages like Perl or Python are fantastic timesavers. I run a Perl course each December, notes available at: `http://www.doc.ic.ac.uk/~dcw/perl2012/`