Building your own C Toolkit

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- Today, I'd like to show you some of the tools in my toolkit, hopefully they'll be useful to you!

We'll cover:

- Basic Tools:
  - Programmer's Editors: Use a single editor well.
  - Automating Compilation (reminder): Use Make.
  - Automating Testing: ruthless testing.
  - Debugging: Use a debugger and know it well.

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- I strongly recommend The Pragmatic Programmer (PP) book, by Hunt & Thomas. The woodworking metaphor comes from there.
- There's a tarball of examples associated with this lecture, tarball 01.list refers to a directory inside the tarball. Each directory contains a README file describing what's in it in great detail.

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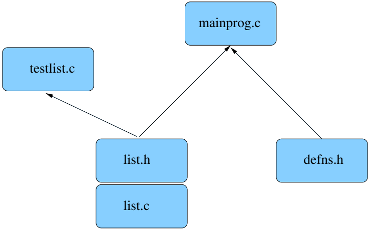
- Others like Emacs, very powerful and extensible. Like Eclipse, Emacs can be a whole development environment.
- Whichever editor you chose, after initial exploration of the possibilities, stick to it, learn it thoroughly and become expert in its use.

When multi-file C programming, eg:



Many files:

- Module list comprising two files (interface list.h and impln list.c).
- Test program testlist.c
- Main program mainprog.c
- Separate basic defns header file defns.h.

Dependencies between the files are vital, determined by the #include structure:

- list.c includes list.h (check implmn vs interface).
- testlist.c includes list.h
- mainprog.c includes list.h and defns.h

Make uses such file dependencies to automatically compile your programs. Details are covered in another lecture.

- Always use make. Keep your Makefile up to date.
- Exercise: why not auto generate your Makefiles?

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- Test programs should check for correct results themselves (essentially, hardcoding the correct answers in them).
- make test could run all test programs in sequence:

```
test:   testprogram1 testprogram2 ...
        ./testprogram1
        ./testprogram2
```

  or invoke a test framework script with testprograms as arguments.
- Exercise: add test target to 01.list to run the obvious `./testlist`, or `./testlist|grep -v ok` to only report failures.

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- Test Driven Development (TDD) writes the test programs before implementing the feature to test.

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- Recompile all source code with gcc flag -g: set `CFLAGS = -Wall -g` in your Makefile, then recompile everything via `make clean all`.
- Start gdb by `gdb PROGRAMNAME`. Inside gdb, type `run COMMANDLINEARGS`. Work with your program until it crashes.
- Back at the gdb prompt: type `where` to see the call frame stack - the sequence of function calls leading to the crash.

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- `frame N` allows you to switch to the Nth function call on the frame stack, i.e. select which of the function calls you want to look at, in order to examine that function's local variables.

- `list` will list 10 lines of the current function.
- `p EXPR` will print any C expression, including global variables and local variables in the current stack frame.
- `whatis VAR` displays the type of VAR.
- `x` is a flexible memory dumper. `x/12c &str` would print out the first 12 bytes of data from `str` in ASCII, `12xb` as hexadecimal etc. `help x` (inside gdb) for more info.

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- You can also set breakpoints (`break LINENO|FUNCTIONNAME`), attach conditions on the breakpoints, single step through your program (`step` and `next`), continue until you hit another breakpoint (`cont`), and even watch variables as they are altered or accessed (`watch, rwatch`).
- Google for gdb tutorial for more info.
- Most important, leave gdb by `quit`.

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- Then I wrote a vi macro bound to an unused key that piped the next paragraph into proto % (current filename). Can do same for forward declarations of static functions using proto -s %.

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- Segmentation faults - gdb where (frame stack) may show it crashes in system libraries.

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  - Rebuild using `make clean all`
  - Run the two examples now!

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- Find dramatic non-linear behaviour around 6-7k iterations on some older lab machines: Twice as slow, CPU %age falls, starts doing I/O.
- What's happening?

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- Conclusion: compile everything with libmem from day one. Save yourself loads of grief, double your confidence.
- Exercise: verify that the list example (in 01.list) runs cleanly with libmem. (Import CFLAGS and LDLIBS from 05.mem-eg's Makefile).

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- Let's try profiling the bugfixed hash module's iterate test program, and see what surprises there may be.

- Profiling iterate 10000 gives the following table:

% time	cumul seconds	self seconds	calls	self us/call	total 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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- hashFree and hashCopy have the same structure, iterating over the array of trees making one call to free_tree/copy_tree per tree. The vast majority of these trees are empty.
- We 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?) while in flight.

- Principle: It's often an excellent idea to import cool features from other languages.
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- I'd dearly love to have that ability in C. If only there was a tool that reads such type definitions and automatically writes a C module that implements them..
- I looked around, couldn't find anything anywhere. Noone but me seemed to have ever thought that such a tool might even be useful!

- So I wrote one! A week or two's work one summer, the result was datadec - in the 09.datadec directory, also installed on DoC linux machines. After installing it, use it as follows:
- In 10.datadec-eg you'll find an input file types.in containing:

```
TYPE {
        intlist =  nil or cons( int first, intlist next );
        illist  =  nil or cons( intlist first, illist next );
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- To generate a C module called datatypes from types.in, invoke:

```
datadec datatypes types.in
```

- datatypes.c and datatypes.h are normal C files, write test programs against their interfaces, use them. Don't modify them!
- But you can modify the input file - suppose you realise that an idtree leaf needs two strings not one. Simply change the type defn and rerun datadec. Now the `idtree_leaf()` constructor takes two arguments not one!

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    - indefinite length dynamic arrays
    - linked lists (single or double linked)
    - queues and priority queues
    - binary trees
    - hashes
    - sets - hashes with no values? trees? sparse arrays?
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- The C standard library fails to provide any of these (C++ provides the Standard Template Library of course).
- 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!

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- Most importantly: enjoy your C programming! Build your toolbox - and let me know if you write any particularly cool tools!