CS631 - Advanced Programming in the UNIX Environment
–
UNIX development tools

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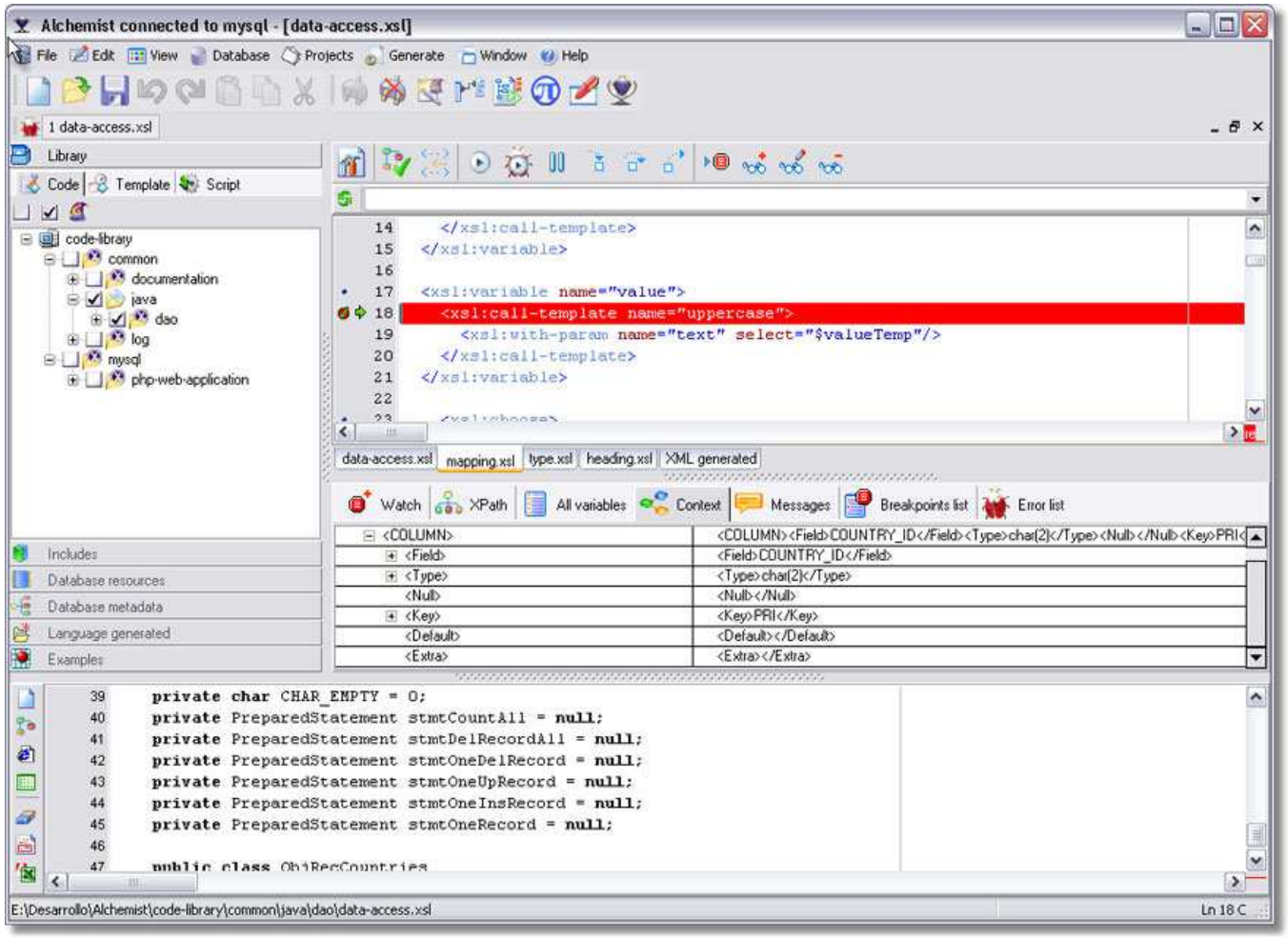
Amended Final Project Requirements

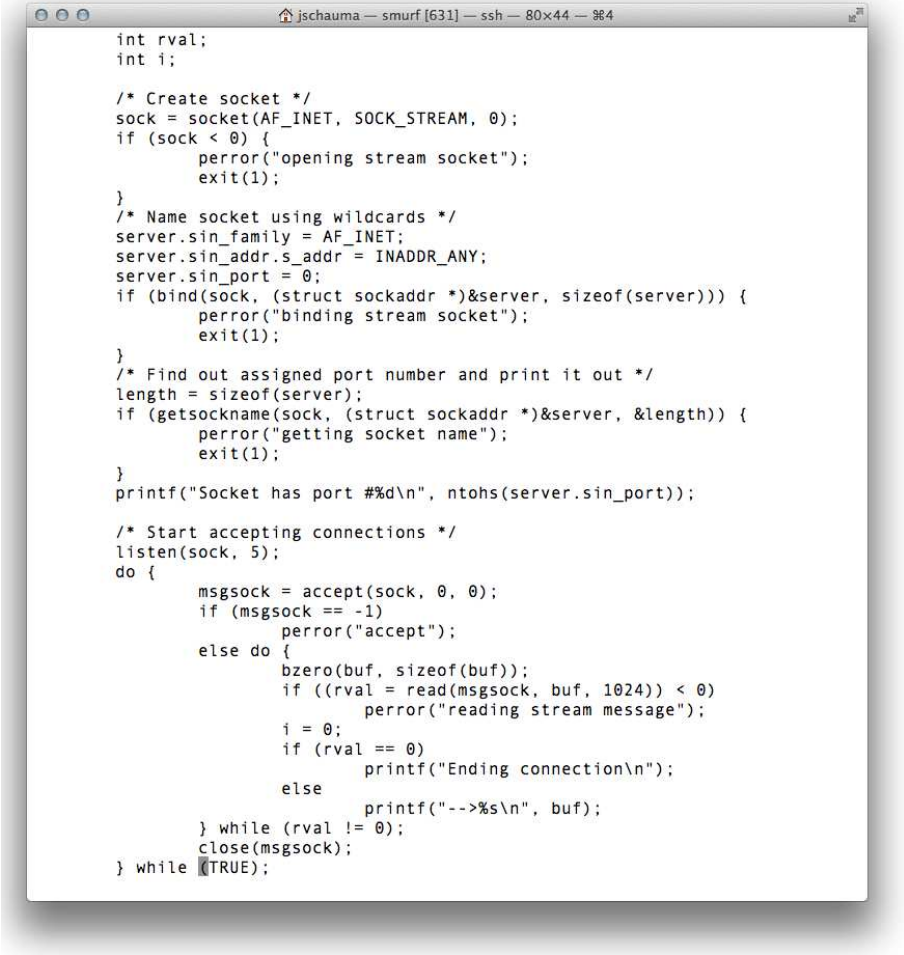
”Real World” edition

- group work:
  - 3-4 people in a team
  - let me know your team composition by next week
  - all people will get the same grade on the final project
- use of `git(1)` required
- use of a `Makefile` required
- code must be split across multiple files
- milestone deliverables (HW3 was the first)
- multi-platform support

Software Development Tools



Software Development Tools



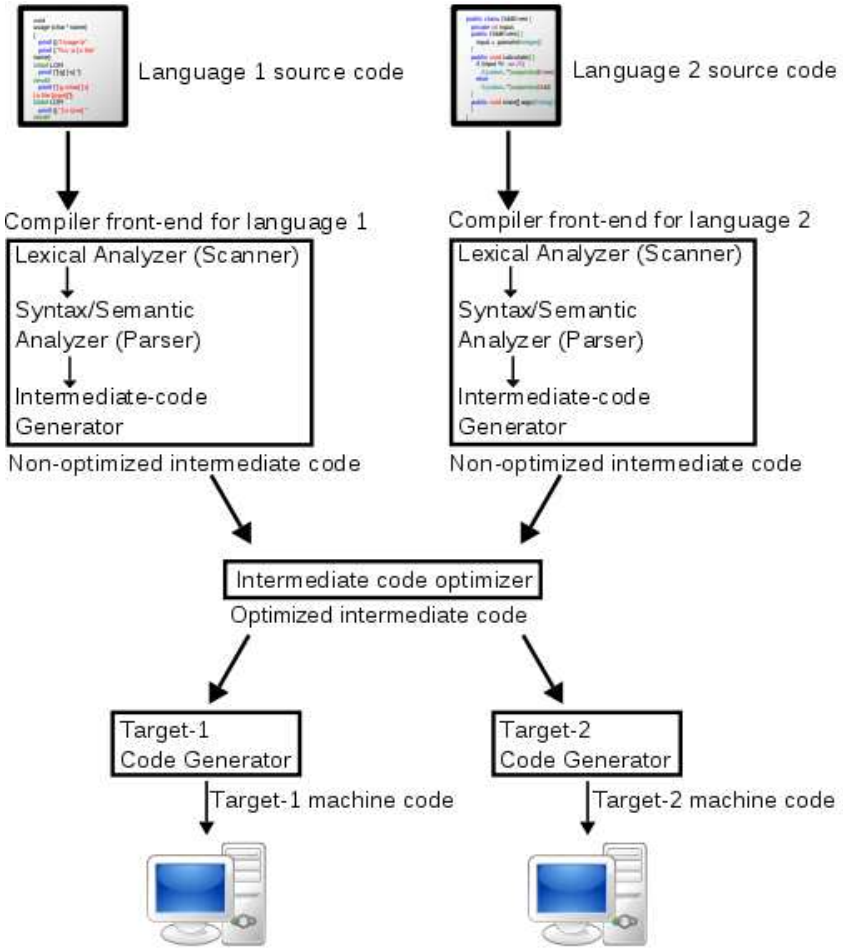
Software Development Tools

UNIX Userland is an IDE – essential tools that follow the paradigm of "Do one thing, and do it right" can be combined.

The most important tools are:

- `$EDITOR`
- the compiler toolchain
- `gdb(1)` – debugging your code
- `make(1)` – project build management, maintain program dependencies
- `diff(1)` and `patch(1)` – report and apply differences between files
- `cvs(1)`, `svn(1)`, `git(1)` etc. – distributed project management, version control

Compilers


Language 1 source code
Language 2 source code
Compiler front-end for language 1
Lexical Analyzer (Scanner)
Syntax/Semantic Analyzer (Parser)
Intermediate-code Generator
Non-optimized intermediate code
Compiler front-end for language 2
Lexical Analyzer (Scanner)
Syntax/Semantic Analyzer (Parser)
Intermediate-code Generator
Non-optimized intermediate code
Intermediate code optimizer
Optimized intermediate code
Target-1 Code Generator
Target-2 Code Generator
Target-1 machine code
Target-2 machine code

Compilers

A compiler translates *source code* from a high-level programming language into *machine code* for a given architecture by performing a number of steps:

- lexical analysis
- preprocessing
- parsing
- semantic analysis
- code generation
- code optimization

Compilers

There are many different closed- and open-source compiler chains:

- Intel C/C++ Compiler (or `icc`)
- Turbo C / Turbo C++ / C++Builder (Borland)
- Microsoft Visual C++
- ...

- Clang (a frontend to LLVM)
- GNU Compiler Collection (or `gcc`)
- Portable C Compiler (or `pcc`)
- ...

The compiler toolchain

The compiler usually performs preprocessing (via `cpp(1)`), compilation (`cc(1)`), assembly (`as(1)`) and linking (`ld(1)`).

Preprocessing

The compiler usually performs preprocessing (via `cpp(1)`), compilation (`cc(1)`), assembly (`as(1)`) and linking (`ld(1)`).

```
$ cd compilechain
$ cat hello.c
$ man cpp
$ cpp hello.c hello.i
$ file hello.i
$ man cc
$ cc -v -E hello.c > hello.i
$ more hello.i
$ cc -v -DFOOD=\"Avocado\" -E hello.c > hello.i.2
$ diff -bu hello.i hello.i.2
```

Compilation

The compiler usually performs preprocessing (via `cpp(1)`), compilation (`cc(1)`), assembly (`as(1)`) and linking (`ld(1)`).

```
$ more hello.i
$ cc -v -S hello.i > hello.s
$ file hello.s
$ more hello.s
```

Assembly

The compiler usually performs preprocessing (via `cpp(1)`), compilation (`cc(1)`), assembly (`as(1)`) and linking (`ld(1)`).

```
$ as -o hello.o hello.s
$ file hello.o
$ cc -v -c hello.s
$ objdump -d hello.o
[...]
```

Linking

The compiler usually performs preprocessing (via `cpp(1)`), compilation (`cc(1)`), assembly (`as(1)`) and linking (`ld(1)`).

```
$ ld hello.o
[...]
$ ld hello.o -lc
[...]
$ cc -v hello.o
[...]
$ ld -dynamic-linker /lib64/ld-linux-x86-64.so.2 \
        /usr/lib/x86_64-linux-gnu/crt1.o         \
        /usr/lib/x86_64-linux-gnu/crti.o hello.o \
        -lc /usr/lib/x86_64-linux-gnu/crtn.o
$ file a.out
$ ./a.out
```

Linking

The compiler usually performs preprocessing (via `cpp(1)`), compilation (`cc(1)`), assembly (`as(1)`) and linking (`ld(1)`).

```
$ cc -v -DFOOD=\"Avocado\" hello.c 2>&1 | more
```

`cc(1)` and `ld(1)`

The compiler usually performs preprocessing (via `cpp(1)`), compilation (`cc(1)`), assembly (`as(1)`) and linking (`ld(1)`).

Different flags can be passed to `cc(1)` to be passed through to each tool as well as to affect all tools.

```
$ cc -v -O2 -g hello.c 2>&1 | more
```

`cc(1)` and `ld(1)`

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The order of the command line flags *may* play a role! Directories searched for libraries via `-L` and the resolving of undefined symbols via `-l` are examples of position sensitive flags.

```
$ cc -v main.c -L./lib2 -L./lib -lldtest 2>&1 | more
```

```
$ cc -v main.c -L./lib -L./lib2 -lldtest 2>&1 | more
```

cc(1) and ld(1)

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The behavior of the compiler toolchain may be influenced by environment variables (eg TMPDIR, SGI_ABI) and/or the compilers default configuration file (MIPSPro's /etc/compiler.defaults or gcc's specs).

```
$ cc -v hello.c
$ TMPDIR=/var/tmp cc -v hello.c
$ cc -dumpspec
```

A Debugger

gdb(1)

The purpose of a debugger such as `gdb(1)` is to allow you to see what is going on "inside" another program while it executes – or what another program was doing at the moment it crashed. `gdb` allows you to

- make your program stop on specified conditions (for example by setting *breakpoints*)
- examine what has happened, when your program has stopped (by looking at the *backtrace*, inspecting the value of certain variables)
- inspect control flow (for example by *stepping* through the program)

Other interesting things you can do:

- examine stack frames: *info frame*, *info locals*, *info args*
- examine memory: *x*
- examine assembly: *disassemble func*

gdb(1)

```
$ cd student
$ make
$ ./a.out -lR ~djd >/dev/null
total 2701553
[...]
Memory fault
$ gdb ./a.out
 run -lR ~djd
Starting program: /home/jschauma/t/student/a.out -lR ~djd
total 2701553
[...]

Program received signal SIGSEGV, Segmentation fault.
0x000000000040214a in print_entries (entryvect=0x6050a0, options=0x605010) at print.c
221                     printf("%10s ", grpentry->gr_name);
```

gdb(1)

```
(gdb) bt
#0  0x000000000040214a in print_entries (entryvect=0x6050a0, options=0x605010) at pri
#1  0x0000000000401ad5 in list_dir_contents (path=0x7fffffffec59 "/home/djd", ftsopts
#2  0x000000000040292e in main (argc=1, argv=0x7fffffffe9e8) at ls.c:57
(gdb) li
216   } else {
217       pwentry = getpwuid(myentryp->fts_statp->st_uid);
218       printf("%8s ", pwentry->pw_name);
219
220       grpentry = getgrgid(myentryp->fts_statp->st_gid);
221       printf("%10s ", grpentry->gr_name);
222   }
223
224   // displaying the size
225   size = (long long)(myentryp->fts_statp->st_size);
(gdb) p grpentry
$1 = (struct group *) 0x0
```

gdb(1)

```
$ cc -g gdb1.c
$ ./a.out
[...]
$ gdb ./a.out
[...]
(gdb) break main
Breakpoint 1 at 0x400603: file gdb1.c, line 10.
(gdb) run
Starting program: /home/jschauma/t/gdb-examples/a.out

Breakpoint 1, main (argc=1, argv=0x7fffffffe9e8) at gdb1.c:10
10 c = fgetc(stdin);
(gdb) n
```

gdb(1)

```
$ ulimit -c unlimited
$ cc -g gdb2.c
$ ./a.out
$ gdb a.out core
bt
[...]
frame 2
li
p buf
kill
watch num
run
```

make(1)

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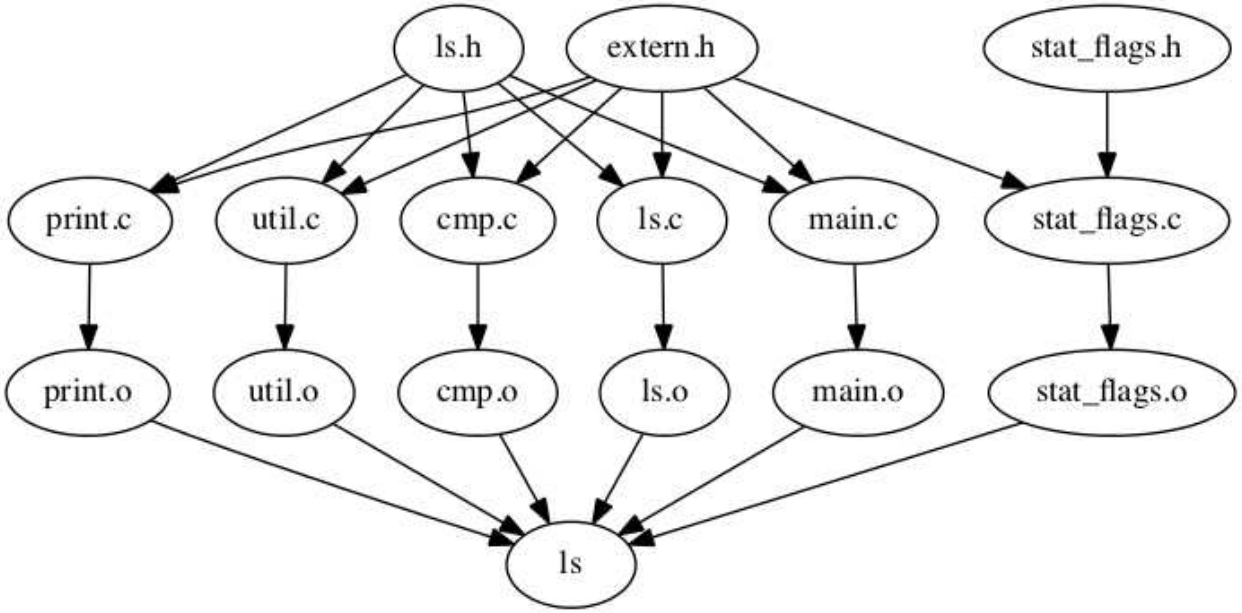
- performs *selective* rebuilds following a *dependency graph*
- allows simplification of rules through use of *macros* and *suffixes*, some of which are internally defined
- different versions of `make(1)` (BSD make, GNU make, Sys V make, ...) may differ (among other things) in
  - variable assignment and expansion/substitution
  - including other files
  - flow control (for-loops, conditionals etc.)

make(1)

```
$ cd make-examples
$ ls *.[ch]
cmp.c       ls.c        main.c        stat_flags.c        util.c
extern.h    ls.h        print.c       stat_flags.h
```



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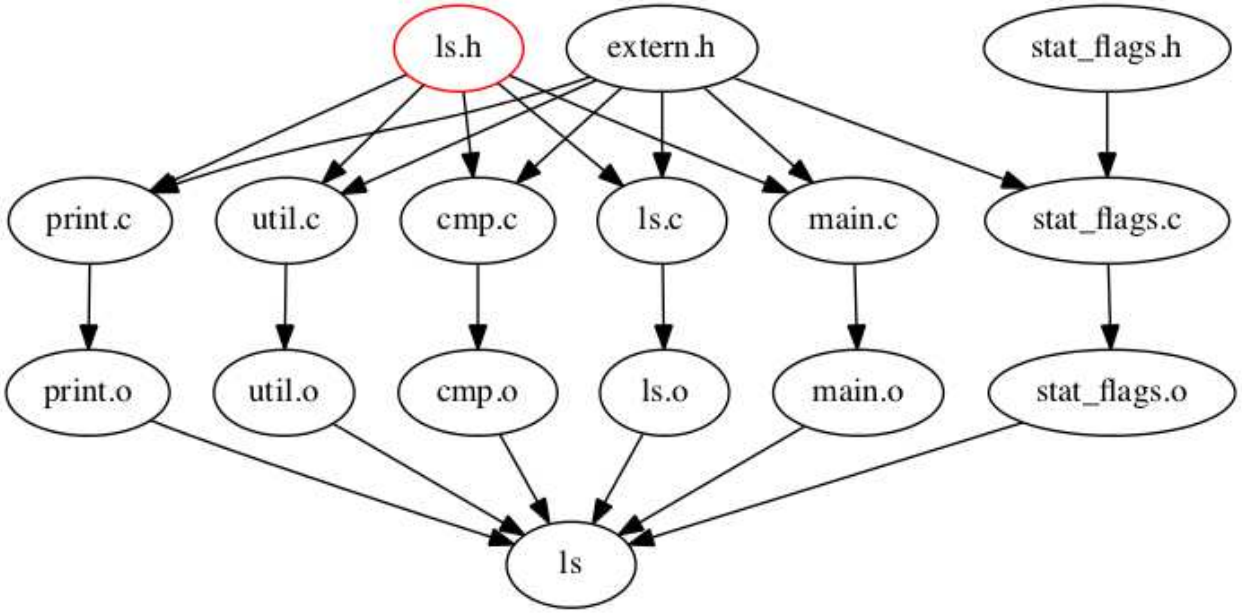

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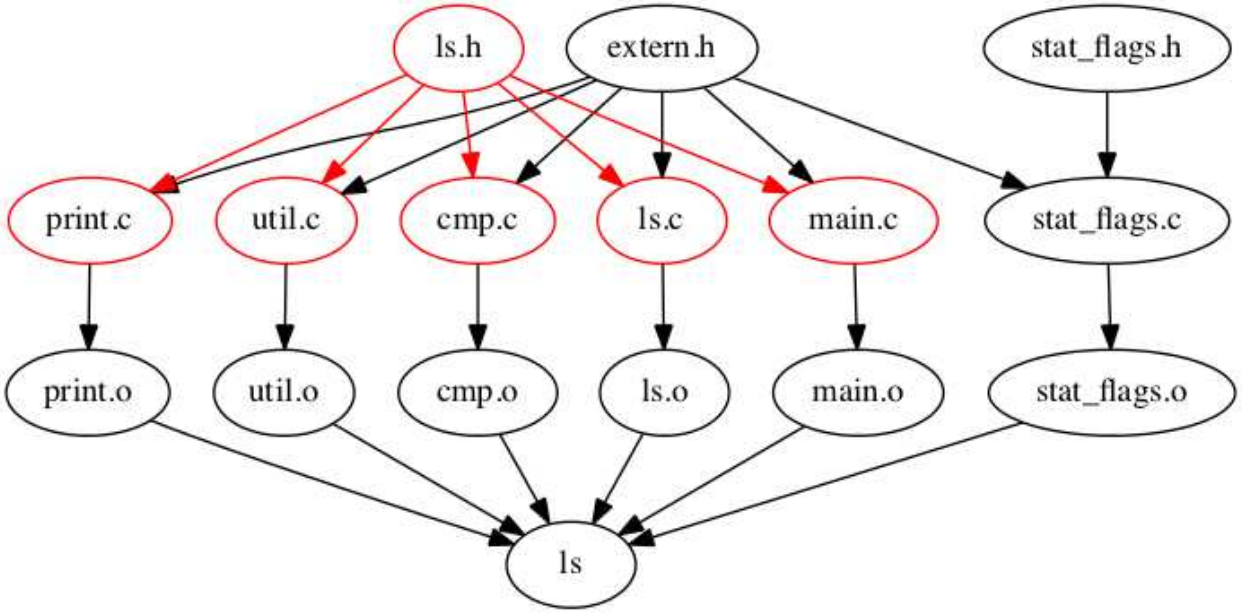

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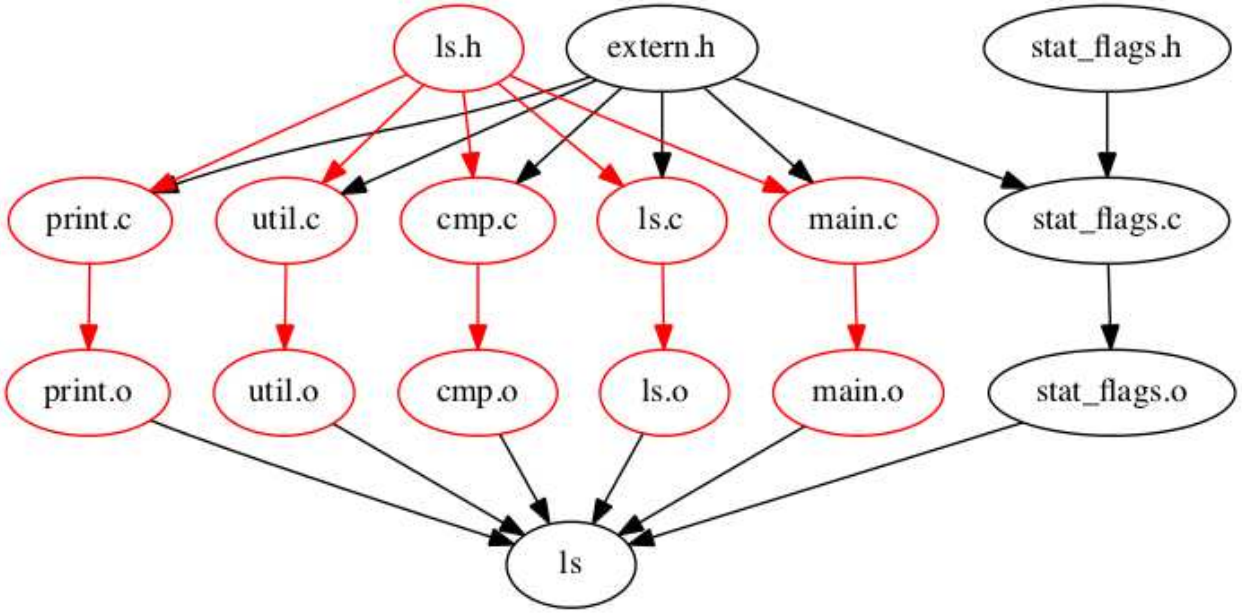

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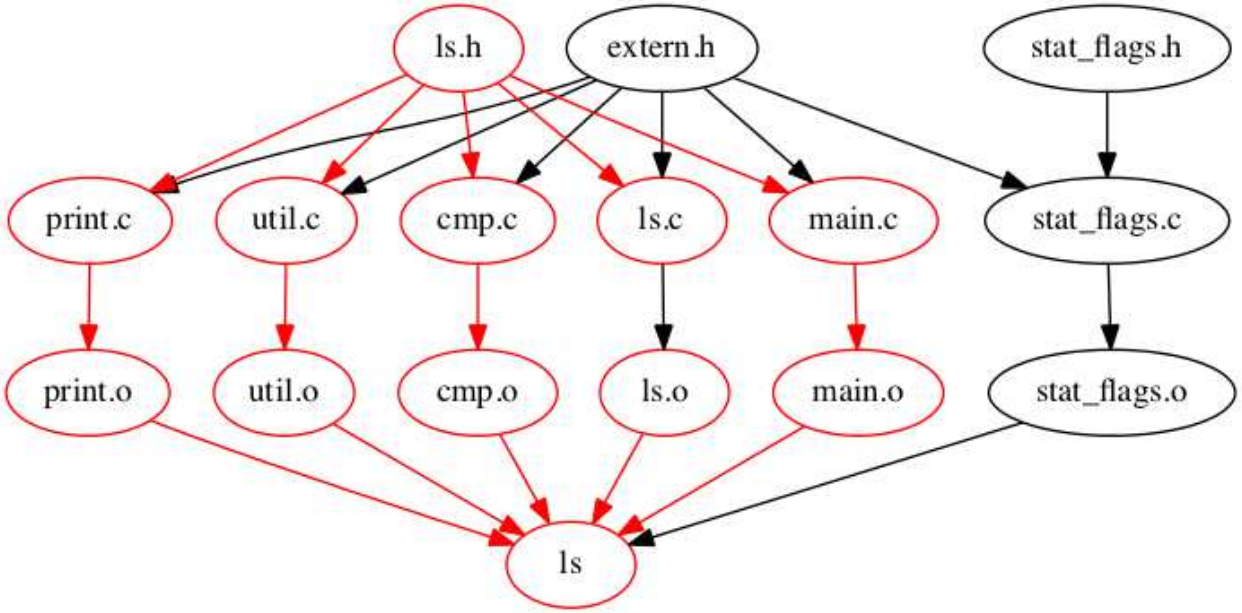

make(1)

```
$ make -f Makefile.1
cc -c cmp.c
cc -c ls.c
cc -c main.c
cc -c print.c
cc -c stat_flags.c
cc -c util.c
cc cmp.o ls.o main.o print.o stat_flags.o util.o -o ls
$ touch ls.h
$ make -f Makefile.1
cc -c cmp.c
cc -c ls.c
cc -c main.c
cc -c print.c
cc -c util.c
cc cmp.o ls.o main.o print.o stat_flags.o util.o -o ls
$
```

make(1)

```
$ make -f Makefile.2
cc    -c -o cmp.o cmp.c
cc    -c -o ls.o ls.c
[...]
cc    -c -o util.o util.c
ls depends on cmp.o ls.o main.o print.o stat_flags.o util.o
cc  cmp.o ls.o main.o print.o stat_flags.o util.o -o ls
$ bmake -f Makefile.2
gcc -pipe -O2  -c cmp.c
gcc -pipe -O2  -c ls.c
[...]
gcc -pipe -O2  -c util.c
ls depends on cmp.o ls.o main.o print.o stat_flags.o util.o
gcc  cmp.o ls.o main.o print.o stat_flags.o util.o -o ls
$
```

make(1)

```
$ make -f Makefile.3
cc -c cmp.c -o cmp.b
cc -c ls.c -o ls.b
cc -c main.c -o main.b
cc -c print.c -o print.b
cc -Wall -g -c stat_flags.c -o stat_flags.bar
cc -Wall -g -c util.c -o util.bar
ls depends on cmp.b ls.b main.b print.b stat_flags.bar util.bar
cc  cmp.b ls.b main.b print.b stat_flags.bar util.bar -o ls
$
```

Priority of Macro Assignments for `make(1)`

1. Internal (default) definitions of `make(1)`
2. Current shell environment variables. This includes macros that you enter on the *make* command line itself.
3. Macro definitions in *Makefile*.
4. Macros entered on the `make(1)` command line, if they follow the *make* command itself.

make(1)

```
$ bmake -f Makefile.4
[...]
$ bmake -f Makefile.2
[...]
$ CFLAGS=-Werror bmake -f Makefile.2
[...]
$ CFLAGS=-Werror bmake -f Makefile.4
[...]
$ bmake CFLAGS=-Werror -f Makefile.2
[...]
$ bmake CFLAGS=-Werror -f Makefile.4
[...]
```

Ed is the standard text editor.

```
$ ed
?
help
?
quit
?
exit
?
bye
?
eat flaming death
?
^C
?
^D
?
```

Ed is the standard text editor.

```
$ ed
a
ed is the standard Unix text editor.
This is line number two.
.
2i

.
%l
3s/two/three/
w foo
q
$ cat foo
```

`diff(1)` and `patch(1)`

`diff(1)`:

- compares files line by line
- output may be used to automatically edit a file
- can produce human “readable” output as well as diff entire directory structures
- output called a *patch*

`diff(1)` and `patch(1)`

`patch(1)`:

- applies a `diff(1)` file (aka *patch*) to an original
- may back up original file
- may guess correct format
- ignores leading or trailing “garbage”
- allows for reversing the patch
- may even correct context line numbers

diff(1) and patch(1)

```
$ diff Makefile.2 Makefile.4
8c8
< #CFLAGS= -Wall -g
---
> CFLAGS= -Wall -g
$ cp Makefile.2 /tmp
$ ( diff -e Makefile.2 Makefile.4; echo w; ) | ed Makefile.2
$ diff Makefile.[24]
$ mv /tmp/Makefile.2 .
$ diff -c Makefile.[24]
$ diff -u Makefile.[24] > /tmp/patch
$ patch </tmp/patch
$ diff Makefile.[24]
```

Revision Control

Version control systems allow you to

- collaborate with others
- simultaneously work on a code base
- keep old versions of files
- keep a log of the who, when, what, and why of any changes
- perform release engineering by creating *branches*

Revision Control

- Source Code Control System (*SSCS*) begat the Revision Control System (*RCS*).
- RCS operates on a single file; still in use for misc. OS config files
- the Concurrent Versions System (*CVS*) introduces a client-server architecture, control of hierarchies
- *Subversion* provides atomic commits, renaming, cheap branching etc.
- *Git*, *Mercurial* etc. implement a *distributed* approach (ie peer-to-peer versus client-server), adding other features (cryptographic authentication of history, ...)

Revision Control

Examples:

`http://cvsweb.netbsd.org/bsdweb.cgi/src/bin/ls/`

`http://svnweb.freebsd.org/base/stable/9/bin/ls/`

`http://git.savannah.gnu.org/cgit/coreutils.git/log/`

Setting up git(1) for your final project

Each team identifies one member to host the repository.

Initialize the source code repository:

```
ssh linux-lab.cs.stevens.edu
mkdir -p ~/git/sws.git
cd ~/git/sws
git --bare init
setfacl -R -m user:teammate1:rwx .
setfacl -R -m user:teammate2:rwx .
setfacl -R -m user:teammate3:rwx .
```

Setting up git(1) for your final project

Add your code from the project directory:

```
ssh linux-lab.cs.stevens.edu
cd ~/cs631/sws
git init
git remote add origin ~/git/sws.git
git config branch.master.merge refs/heads/master
git config branch.master.remote origin
git config --global user.name "Your Full Name"
git config --global user.email $USER@stevens.edu
git add *
git commit -m "initial import of all files"
git push origin master
```

Setting up git(1) for your final project

Check out a copy on a local host and make changes:

```
local$ git clone linux-lab.cs.stevens.edu:git/sws.git
local$ cd sws
local$ $EDITOR README
local$ git add README
local$ git commit README
local$ git push

linux-lab$ cd ~/cs631/sws
linux-lab$ git pull
linux-lab$ $EDITOR ...
linux-lab$ git add ...; git commit; git push
```

Homework

Generate an ssh key pair and send me the *public* key.
See `ssh-keygen(1)`.

Links

Revision Control:

`http://cvsbook.red-bean.com/cvsbook.html`

`http://svnbook.red-bean.com/`

`http://git-scm.com/`

GDB:

`http://sources.redhat.com/gdb/current/onlinedocs/gdb_toc.html`

`http://heather.cs.ucdavis.edu/~matloff/UnixAndC/CLanguage/Debug.html`

`http://www.unknownroad.com/rtfm/gdbtut/gdbtoc.html`