Lecture 6

UNIX Development Tools

Software Development Tools

Types of Development Tools

- Compilation and building: **make**
- Managing files: **RCS**, **SCCS**, **CVS**
- Editors: **vi**, **emacs**
- Archiving: **tar**, **cpio**, **pax**, **RPM**
- Configuration: **autoconf**
- Debugging: **gdb**, **dbx**, **prof**, **strace**, **purify**
- Programming tools: **yacc**, **lex**, **lint**, **indent**

Make

(the awesome build system!)

Make

- **make**: A program for building and maintaining computer programs
  - developed at Bell Labs around 1978 by S. Feldman (now at IBM)

- Instructions stored in a special format file called a "**makefile**".

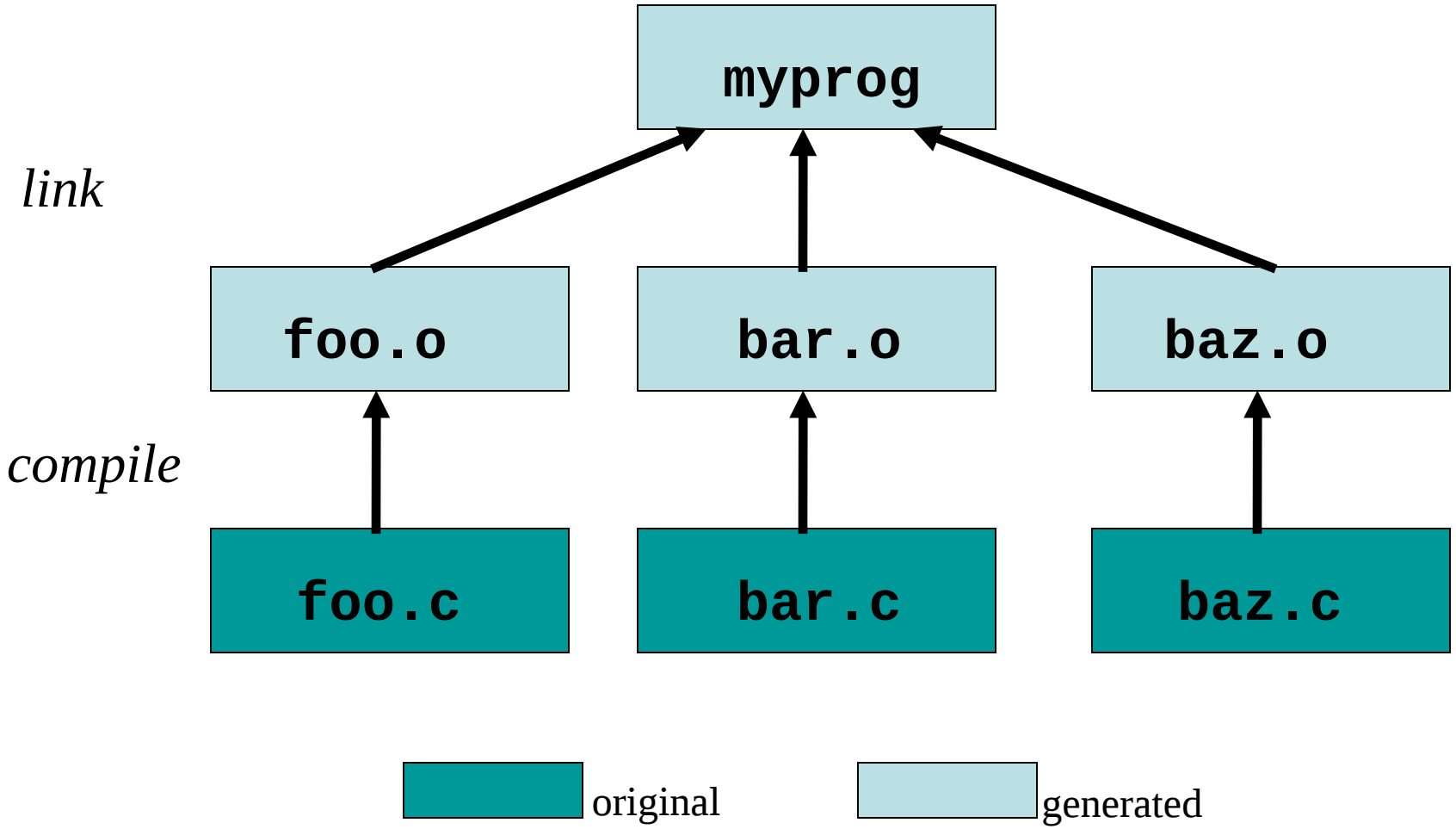
Make Features

- Contains the build instructions for a project
  - Automatically updates files based on a series of dependency rules
  - Supports multiple configurations for a project
- Only re-compiles necessary files after a change (conditional compilation)
  - Major time-saver for large projects
  - Uses timestamps of the intermediate files
- Typical usage: executable is updated from object files which are in turn compiled from source files

Compilation Phases

Component	Input	Output
preprocessor	source code	pre-processed source code
compiler	pre-processed source code	assembly source code
assembler	assembly source code	object file
linker	object files	executable file

Dependency Graph



Makefile Format

- Rule Syntax:

  <target>: <dependency list>

  <command>

  - The *<target>* is a list of files that the command will generate
  - The *<dependency list>* may be files and/or other targets, and will be used to create the target
  - It ***must*** be a **tab** before *<command>*, or it won't work
  - The first rule is the default *<target>* for *make*

Examples of Invoking Make

- **`make -f makefile`**
- **`make target`**
- **`make`**
  - looks for file **makefile** or **Makefile** in current directory, picks first target listed in the **makefile**

Make: Sequence of Execution

- Make executes all commands associated with *target* in **makefile** if one of these conditions is satisfied:
  - file ***target*** does not exist
  - file ***target*** exists but one of the source files in the ***dependency list*** has been modified more recently than ***target***

Example Makefile

```
# Example Makefile
CC=g++
CFLAGS=-g –Wall -DDEBUG

foobar: foo.o bar.o
        $(CC) $(CFLAGS) –o foobar foo.o bar.o

foo.o: foo.cpp foo.h
        $(CC) $(CFLAGS) –c foo.cpp

bar.o: bar.cpp bar.h
        $(CC) $(CFLAGS) –c bar.cpp

clean:
        rm foo.o bar.o foobar
```

Make Power Features

- Many built-in rules
  - e.g. C compilation
- “Fake” targets
  - Targets that are not actually files
  - Can do just about anything, not just compile
  - Like the “*`clean`*” target
- Forcing re-compiles
  - *`touch`* the required files
  - *`touch`* the Makefile to rebuild everything

Make Patterns and Variables

- Variables (macros):
  - **`VAR = <rest of line>`** Set a variable
  - **`$(VAR)`** Use a variable
- Suffix Rules
  - **`.c.o:`** specifies a rule to build **x.o** from **x.c**
  - Default:

```
.c.o:
  $(CC) $(CFLAGS) -c $<
```

- Special:
  - **`$@:`** target
  - **`$<:`** dependency list
  - **`$*:`** target with suffix deleted

Version Control

Version Control

- Provide the ability to store/access and protect all of the versions of source code files
- Provides the following benefits:
  - If program has multiple versions, it keeps track only of differences between multiple versions.
  - Multi-user support. Allows only one person at the time to do the editing.
  - Provides a way to look at the history of program development.

Ancient Version Control Systems

- **SCCS**: UNIX Source Code Control System
  - Rochkind, Bell Labs, 1972.
- **RCS**: Revision Control System
  - Tichy, Purdue, 1980s.
- **CVS**: Concurrent Versions System
  - Grune, 1986, Berliner, 1989.

Modern Version Control Systems

- **SVN**: Replaced CVS.
  - Apache Foundation, 2000.
- **Git**: Popular alternative to SVN.
  - Torvalds, Hamano, 2005.
- **Mercurial**: Flexible Git alternative.
  - Mackall, 2005.

Archiving Tools

tar: Tape ARchiver

- **tar**: general purpose archive utility (not just for tapes)
  - Usage: **`tar [options] [files]`**
  - Originally designed for maintaining an archive of files on a magnetic tape.
  - Now often used for packaging files for distribution
  - If any files are subdirectories, **tar** acts on the entire subtree.

tar: archiving files options

- **`c`** creates a tar-format file
- **`f filename`** specify filename for tar-format file,
  - Default is `/dev/rmt0`.
  - If **`-`** is used for filename, standard input or standard output is used as appropriate
- **`v`** verbose output
- **`x`** allows to extract named files

tar: archiving files (continued)

- **t**	generates table of contents
- **r**	unconditionally appends the listed files to the archive files
- **u**	appends only files that are more recent than those already archived
- **L**	follow symbolic links
- **m**	do not restore file modification times
- **l**	print error messages about links it cannot find

cpio: copying files

- **cpio:** copy file archives in from or out of tape or disk or to another location on the local machine
- Similar to **tar**
- Examples:
  - **Extract:** `cpio -idtu [patterns]`
  - **Create:** `cpio -ov`
  - **Pass-thru:** `cpio -pl directory`

cpio (continued)

- **cpio -i [dtum] [patterns]**
  - Copy in (extract) files whose names match selected patterns.
  - If no pattern is used, all files are extracted
  - During extraction, older files are not extracted (unless **-u** option is used)
  - Directories are not created unless **–d** is used
  - Modification times not preserved with **-m**
  - Print the table of contents: **-t**

cpio (continued)

- **`cpio -ov`**
  - Copy out a list of files whose names are given on the standard input. **`-v`** lists files processed.
- **`cpio -p [options] directory`**
  - Copy files to another directory on the same system. Destination pathnames are relative to the named directory
  - Example: To copy a directory tree:
    - **`find . -depth -print | cpio -pdumv /mydir`**

pax: replacement for cpio and tar

- **P**ortable **A**rchive e**X**change format
- Part of POSIX
- Reads/writes **cpio** and **tar** formats
- Union of **cpio** and **tar** functionality
- Files can come from standard input or command line
- Sensible defaults
  - **`pax –wf archive *.c`**
  - **`pax –r < archive`**

Distributing Software

- Pieces typically distributed:
  - Binaries
  - Required runtime libraries
  - Data files
  - Man pages
  - Documentation
  - Header files
- Typically packaged in an archive:
  - e.g., **`perl-solaris.tgz`** or **`perl-5.8.5-9.i386.rpm`**

Packaging Source: autoconf

- Produces shell scripts that automatically configure software to adapt to UNIX-like systems.
  - Generates configuration script (configure)
- The configure script checks for:
  - programs
  - libraries
  - header files
  - typedefs
  - structures
  - compiler characteristics
  - library functions
  - system services

  and generates makefiles

Installing Software From Tarballs

```
tar xzf <gzipped-tar-file>
cd <dist-dir>
./configure
make
make install
```

Debuggers

(and how to use them!)

Debugging

- The ideal:

  Do it right the first time

- The reality:

  Bugs happen

- The goal:

  Exterminate, quickly and efficiently

Debuggers

- Advantages over the “old fashioned” way:
  - you can step through code as it runs
  - you don’t have to modify your code
  - you can examine the entire state of the program
    - call stack, variable values, scope, etc.
  - you can modify values in the running program
  - you can view the state of a crash using core files

Debuggers

- The **GDB** or **DBX** debuggers let you examine the internal workings of your code while the program runs.
  - Debuggers allow you to set *breakpoints* to stop the program's execution at a particular point of interest and examine variables.
  - To work with a debugger, you first have to recompile the program with the proper debugging options.
  - Use the **`-g`** command line parameter to **cc, gcc,** or **CC**
    - Example: **`cc -g -c foo.c`**

Using the Debugger

- Two ways to use a debugger:
  1. Run the debugger on your program, executing the program from within the debugger and see what happens
  2. Post-mortem mode: program has crashed and core dumped
     - You often won't be able to find out exactly what happened, but you usually get a stack trace.
     - A stack trace shows the chain of function calls where the program exited ungracefully
     - Does not always pinpoint what caused the problem.

GDB, the GNU Debugger

- Text-based, invoked with:
  gdb [<programfile> [<corefile>|<pid>]]
- Argument descriptions:
  <*programfile* > executable program file
  <*corefile*> core dump of program
  <pid> process id of already running program
- Example:
  gdb ./hello
- Compile <*programfile*> with *–g* for debug info

Basic GDB Commands

- General Commands:

  file [<file>] selects <*file*> as the program to debug
  run [<args>] runs selected program with arguments <*args*>
  attach <pid> attach gdb to a running process <*pid*>
  kill kills the process being debugged
  quit quits the gdb program
  help [<topic>] accesses the internal help documentation

- Stepping and Continuing:

  c[ontinue] continue execution (after a stop)
  s[tep] step one line, entering called functions
  n[ext] step one line, without entering functions
  finish finish the function and print the return value

GDB Breakpoints

- Useful breakpoint commands:

b[reak] [<where>]	sets breakpoints. *<where>* can be a number of things, including a hex address, a function name, a line number, or a relative line offset
[r]watch <expr>	sets a watchpoint, which will break when *<expr>* is written to [or read]
info break[points]	prints out a listing of all breakpoints
clear [<where>]	clears a breakpoint at *<where>*
d[elete] [<nums>]	deletes breakpoints by number

Playing with Data in GDB

- Commands for looking around:

list [<where>]	prints out source code at *<where>*
search <regexp>	searches source code for *<regexp>*
backtrace [<n>]	prints a backtrace *<n>* levels deep
info [<what>]	prints out info on *<what>* (like local variables or function args)
p[rint] [<expr>]	prints out the evaluation of *<expr>*

- Commands for altering data and control path:

set <name> <expr>	sets variables or arguments
return [<expr>]	returns *<expr>* from current function
jump <where>	jumps execution to *<where>*

Tracing System Calls

- Most operating systems contain a utility to monitor system calls:
  - Linux: **strace**, Solaris: **truss**, SGI: **par**

```
   27mS[  1]                 : close(0) OK
   27mS[  1]                 : open("try.in", O_RDONLY, 017777627464)
   29mS[  1]                 : END-open() = 0
   29mS[  1]                 : read(0, "1\n2\n|/bin/date\n3\n|/bin/sleep 2", 2048) = 31
   29mS[  1]                 : read(0, 0x7fff26ef, 2017) = 0
   29mS[  1]                 : getpagesize() = 16384
   29mS[  1]                 : brk(0x1001c000) OK
   29mS[  1]                 : time() = 1003207028
   29mS[  1]                 : fork()
   31mS[  1]                 : END-fork() = 1880277
   41mS[  1]                (1864078): was sent signal SIGCLD
   31mS[  2]                 : waitsys(P_ALL, 0, 0x7fff2590, WTRAPPED|WEXITED, 0)
   42mS[  2]                 : END-waitsys(P_ALL, 0, {signo=SIGCLD, errno=0,
code=CLD_EXITED, pid=1880277, status=0}, WTRAPPED|WEXITED, 0) = 0
   42mS[  2]                 : time() = 1003207028
```