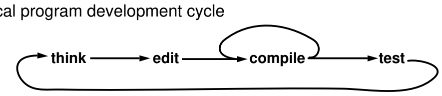
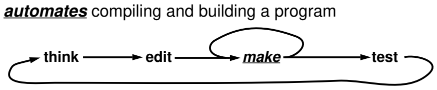
Make

- Typical program development cycle

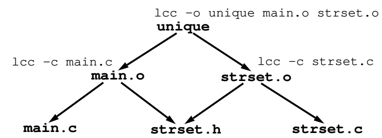


- Potential problems
  - edit a file, but forget to compile it
  - edit an interface, but forget to compile ***all*** the files that ***depend*** on it
  - do more compilation than is necessary
- **`make`** ***automates*** compiling and building a program



Dependency Graphs

- make processes a ***dependency graph***



  - each node represents a ***file***
  - each node is annotated with the ***command*** that “makes” the file
- To make node *X*
  - make all files *X* depends on (those ***modified more recently*** than *X*)
  - update *X* using the associated command
  - if **`strset.h`** or **`main.c`** is newer than **`main.o`**
  - re-make **`main.o`** with **`lcc -c main.c`**”

Makefiles

- **`makefile`** or **`Makefile`** **specifies the dependency graph of make**

  targets: dependents
  commands

```
unique:    main.o strset.o
           lcc -o unique main.o strset.o

main.o:    main.c strset.h
           lcc -c main.c

strset.o:  strset.c strset.h
           lcc -c strset.c
```

- To invoke **`make`**

  `make` ***targets*** ... **`make strset.o`** **`make unique`**

- With no arguments, **`make`** makes the ***first*** target listed in **`makefile`**

```
% make
lcc -c main.c
lcc -c strset.c
lcc -o unique main.o strset.o
```

```
% touch strset.c
% make
    lcc -c strset.c
    lcc -o unique main.o strset.o
```


Built-ins and Macros

- **`make`** contains ***built-in*** dependencies and commands

  a “**`.o`**” file is assumed from a “**`.c`**” file by the C compiler

```
unique:     main.o strset.o
            lcc -o unique main.o strset.o

main.o strset.o: strset.h
```

- **`make`** has a simple ***macro*** facility; macros communicate with built-in commands and simplify **`makefile`**s

```
CC=lcc -A
CFLAGS=-g
LDFLAGS=-g
STRSET=strset0
OBJS=main.o $(STRSET).o

a.out: $(OBJS)
       $(CC) $(LDFLAGS) $(OBJS)

$(OBJS):  strset.h
```

```
% make -n
lcc -A -g -c main.c
lcc -A -g -c strset0.c
lcc -A -g main.o strset0.o
% make -n STRSET=strset1
lcc -A -g -c main.c
lcc -A -g -c strset1.c
lcc -A -g main.o strset1.o
% setenv STRSET strset1
% make -e
lcc -A -g -c main.c
lcc -A -g -c strset1.c
lcc -A -g main.o strset1.o
%
```

Dummy Targets, Prefixes, and Built-in Macros

- "Dummy" targets for common command sequences

```
install: a.out
         cp a.out unique
         strip unique

clean:
         -rm *.o core

clobber: clean
         rm -f a.out unique
```

"–" prefix ignores errors

make clean removes "**.o**" and **core** files

- Dummy targets can be created if only for their modification time

```
FILES=main.c strset.h strset0 strset1.c
...
print:   $(FILES)
         @enscript $?
         @touch print
```

$? macro expands into "younger" dependents

"@" prefix suppresses command echoing

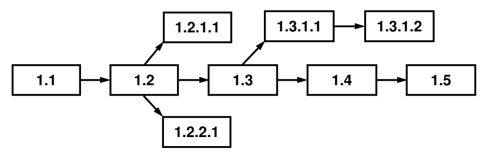
- Use dummy targets for all "program maintenance" tasks

clean	**install**	**print**
release	**submit**	**test**

- **Don't *overuse* dummy targets and macros**

Version-Control Tools

- Software systems ***evolve*** — they advance in steps or ***versions***
  - repair bugs
  - add performance improvements and new features
  - add versions for other platforms (SPARC, MIPS, x86, ...)
- Might have to retrieve ***old*** versions
- ***Version-control*** tools help maintain versions of programs, or any files
- ***Revision trees***



Revision Control System

- "Checking in" a file creates a new version, including the initial version

  ci main.c

  creates the version file **main.c,v** that holds **main.c** as version 1.1

  deletes **main.c**

- "Checking out" a file retrieves a copy of the latest version

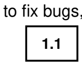
co main.c	checks out a ***read-only*** copy
lcc -c main.c	
co -l main.c	checks out a ***read/write*** copy, ***locks*** **main.c,v**
emacs main.c	
lcc -c main.c	
ci main.c	checks in new **main.c** as version 1.2

- Options specify explicit versions for **co** and **ci**

co -r1.2 main.c	checks out a read-only copy of version 1.2 **main.c**
co -l1.2 main.c	checks out a read/write copy of version 1.2 **main.c**
ci -r2 main.c	checks in a new "release" of **main.c**

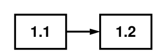
Branching

- Branching occurs to fix bugs, enhance old versions, ...
-



ci main.c

co -l main.c; emacs; ... ; ci main.c



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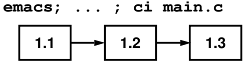
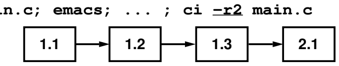
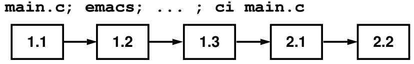


co -l main.c; emacs; ... ; ci -r2 main.c



co -l main.c; emacs; ... ; ci main.c

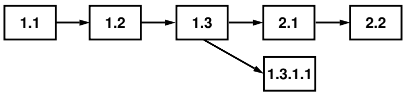


- What if you would like to fix and enhance version 1.3?

Branching, cont'd

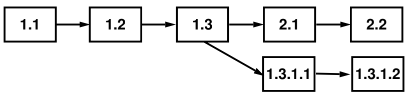
- Create a ***branch*** at version 1.3

  co <u>-l1.3</u> main.c; emacs; ... ; ci <u>-r1.3.1</u> main.c



- Extra revision number in 1.3.1.***1*** allows for subsequent revisions

  co <u>-l1.3.1</u> main.c; emacs; ... ; ci <u>-r1.3.1</u> main.c



- See RCS man pages for information on more options, commands, ...

Using RCS with Make

- Using RCS with **make**

  ***.c** depends on ***.c,v**

```
main.c:     main.c,v
            co main.c
```

  RCS automatically looks in the directory **RCS** for **,v** files

```
main.c:     RCS/main.c,v
            co main.c
```

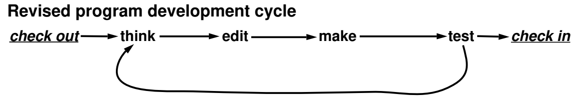
  "**make clobber**" should remove **.c** files

```
clobber:    clean
            rm -f wf main.c parse.c table.c
```

  or, if **rcsclean** is available

```
clobber:    clean
            rm -f wf; rcsclean *.[ch]
```

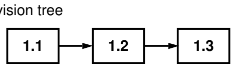
- **Revised program development cycle**



RCS Implementation

- Revisions are stored in the version file in ***differential form***

  if **main.c** has the revision tree



main.c,v holds	all of version 1.3 ***edit script*** to convert 1.3 to 1.2 ***edit script*** to convert 1.2 to 1.1

- RCS revisions are ***backward deltas*** . Why?

- Other systems,such as SCCS use ***forward deltas***

version file holds	all of version 1.1 edit script to convert 1.1 to 1.2 edit script to convert 1.2 to 1.3