

File Dependencies: make

Steven J Zeil

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make

make is a command/program that enacts builds according to a dependency graph expressed in a *makefile*.

- **make** devised by Dr. Stuart Feldman of Bel Labs in 1977
- Long a standard component of *nix systems
 - GNU make is a popular modern variant

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1 The make Command

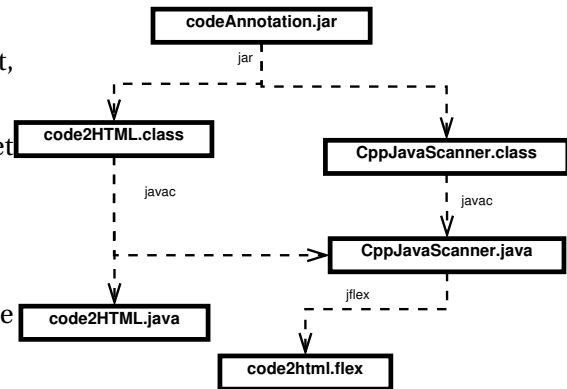
make

- **make** looks for its instructions in a file named, by default, `makefile` or `Makefile`
- The **make** command can name any file in the graph as the target to be built, e.g.,

`make CppJavaScanner.class`

- If no target is given, **make** builds the first file described in the `makefile`

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make Options

Some useful options:

- n Print the commands that **make** would issue to rebuild the target, but don't actually perform the commands.
- k "Keep going." Don't stop the build at the first failure, but continue building any required targets that do not depend on the one whose construction has failed.
- f *filename* Use *filename* instead of the default `makefile`/`Makefile`

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2 makefiles

makefiles

At its heart, a makefile is a collection of rules.

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2.1 Rules

Rules

- A *rule* describes how to build a single file of the project.
Each rule indicates
 - The *target* file to be constructed
 - The *dependencies*: the other files in this project from which the target is constructed.
 - The *commands* that must be executed to construct the target from its dependencies.
- Rules may appear in any order

- Except that the first rule's target is the default built by **make** when no explicit target is specified in the command line.

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Rules (cont.)

- A rule has the form

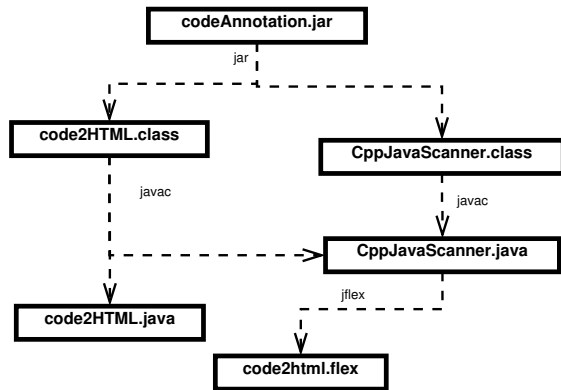
```
target: dependencies  
        commands
```

where

- *target* is the target file,
- *dependencies* is a space-separated list of files on which the target is dependent
- *commands* is a set of zero or more commands, one per line, each preceded by a Tab character.

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Rule Examples



codeAnnotation.jar: code2HTML.class CppJavaScanner.class
 jar tvf codeAnnotation.jar code2HTML.class CppJavaScanner.class

CppJavaScanner.class: CppJavaScanner.java
 javac CppJavaScanner.java

code2HTML.class: code2HTML.java CppJavaScanner.java
 javac code2HTML.java

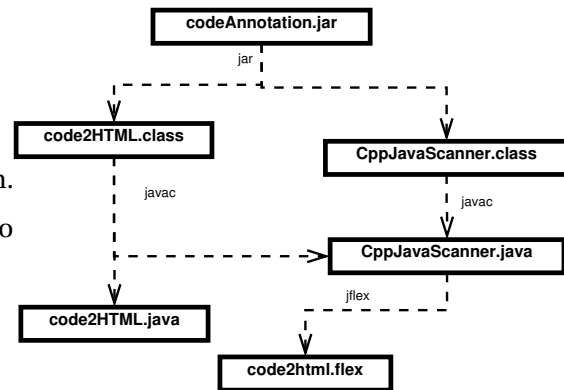
CppJavaScanner.java: code2html.flex
 java -cp JFlex.jar JFlex.Main code2html.flex

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Why is This Better than Scripting?

Suppose that we edit `code2html.java` and then invoke **make**

- Only one **javac** will be issued, after which the **jar** command is run.
- **make** has determined the minimum number of steps required to rebuild after a change.



How make Works

- Construct the dependency graph from the target and dependency entries in the makefile
- Do a topological sort to determine an order in which to construct targets.
- For each target visited, invoke the commands if the target file does not exist or if any dependency file is newer
 - Relies on file modification dates

2.2 Variables

Variables

A makefile can use variables to simplify the rules or to add flexibility in configuring the makefile.

- All variables hold strings.
- Variables are initialized by a simple assignment

variable = value

- Variables are immutable (constants)
- Assignments may appear within the makefile or in the command line, e.g.:

```
make JOPTIONS=-g codeAnnotation.jar
```

.....

Referencing Variables

- Variables are referenced as \$(variable) or \${variable}, e.g.,

```
CppJavaScanner.class: CppJavaScanner.java  
javac $(JOPTIONS) CppJavaScanner.java
```

```
code2HTML.class: code2HTML.java CppJavaScanner.java  
javac $(JOPTIONS) code2HTML.java
```

.....

Adding Power to Variables

GNU make adds some special extensions useful in setting up variables.

- Globbing:

```
SOURCEFILES=$(wildcard src/*.cpp)
```

collects a list of all C++ compilation units in the filenamesrc directory

- Substitutions:

```
OBJFILES=$(SOURCEFILES:%.cpp=%.o)
```

collects a list of all object code files expected by compiling those compilation units.

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Example: Using variables

This allows us to write a “generic” rule for compiling C++ programs:

```
PROGRAM=myProgramName
SOURCEFILES=$(wildcard src/*.cpp)
OBJFILES=$(SOURCEFILES:%.cpp=%.o)

$(PROGRAM): $(OBJFILES)
    g++ -o $(PROGRAM) $(OBJFILES)
```

- This is technically, incomplete.

- We have not explained how to produce a .o file from a .cpp
- Nonetheless, it would work on some systems for the initial build, because they have an “implicit” rule for working with C++
 - Still not a good solution by itself - dependencies on .h files have not been captured.

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2.3 Implicit Rules and Patterns

Implicit Rules and Patterns

- Implicit rules describe how to produce a single “kind” (extension) of file from another.
 - All make implementations will have some common implicit rules.
 - You can modify the list of implicit rules.
- Pattern rules are a GNU extension for writing “generic” rules
 - Implicit rules could, for the most part, be written as patterns
 - But patterns offer some additional flexibility

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Implicit Rules

An implicit rule looks like

```
.ext_1.ext_2:  
    commands
```

where ext_1 and ext_2 are file extensions, and *commands* are the commands used to convert a file with the first extension into a file with the second.

Example:

```
.cpp.o:  
    g++ -g -c $<
```

- the *implicit variable* \$< holds the dependency file
- Also commonly used, \$@ denotes the target file.

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Using Implicit Rules

The extensions used in implicit rules must be declared:

```
.SUFFIXES: .cpp .o
```

An implicit rule will be used when a target ends in one of these suffixes and

- there is no rule listing that file as a target, or
- the rule listing that file as a target has no commands

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Implicit Rule Example

```
PROGRAM=myProgramName
SOURCEFILES=src/main.cpp src/adt.cpp
OBJFILES=$(SOURCEFILES:%.cpp=%.o)
.SUFFIXES: .cpp .o
```

```
.cpp.o:
```

```
    g++ -g -c $<
```

```
$(PROGRAM): $(OBJFILES)
```

```
    g++ -o $(PROGRAM) $(OBJFILES)
```

```
src/adt.o: adt.cpp adt.h
```

- Both main.cpp and adt.cpp will be compiled on the initial build.
- If adt.h is subsequently modified, then adt.cpp would be re-compiled.

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Pattern Rules

A pattern rule looks like a regular rule, but uses '%' as a wildcard in the target and one of their dependencies:

```
src/test/java/%.class: src/test/java/%.java junit4.jar
    javac -cp junit4.jar -g src/test/java/%*.java
```

- Another implicit variable, \$* contains the string matched by the % wildcard.

- One advantage of pattern rules, is that we can add dependencies on other files e.g., `junit.jar`

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3 Working with Make

3.1 Touching Files

Modification Dates

make

- compares the modification dates of targets and dependencies to determine if the target is out of date.
- uses the success/fail status value returned by commands to determine if construction of a target was successful.

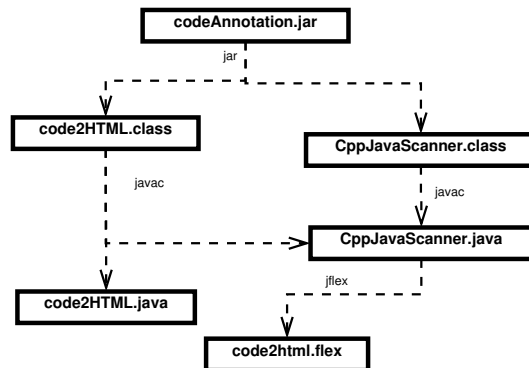
Although this is fairly robust, there are ways to fool **make**

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Touching a File

- The **touch** command in *nix sets a files modification date to the current time, without affecting the contents of the file.

What would happen if we touched `code2html.flex`?
Sometimes this is a useful thing to do on purpose.



Inadvertant Touches

Suppose we had our code annotation project in a directory `project1` and did the following:

```
> cd project1
> make
> cd ..
> cp -rf project1 project2
> cd project2
> make
```

What would be re-built by the second **make**?

- Almost impossible to tell. All of the files in `project2` would have create/modify dates within a second of each other. Ordering, if any, would be arbitrary.
 - (better to have done `cp -arf project1 project2`)

Inadvertant Touches

Suppose we had our code annotation project in a directory `project1` and did the following:

```
> cd project1
> make
> cd ..
> cp -rf project1 project2
> cd project2
> make
```

- Similarly, successive calls to **make** can sometimes be confused if the time between creation of some intermediate targets is within a single clock “tick”
- Clock drift between different machines (particular a command server and a file server) can be particularly troublesome.

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Created != Success

- Some commands we might give to create a target will create no file if the ocmmand fails.
 - e.g., **g++** does not create a `.o` file if compilation errors occur
- Others will create some kind of file anyway.
 - E.g., any command that is invoked with output redirection,
`command > target`

- which could cause **make** to assume that the target need not be re-constructed the next time around.
 - * Some **make** programs explicitly delete targets if the command fails.

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3.2 Artificial Targets

Fooling make Again

A creative way to fool **make**:

What happens if we give a rule whose commands never actually create the target?

```
target: dependency1 dependency2
    echo Nope. Not going make that target!
```

- The first time we run **make**, the dependencies will be created and the **echo** performed.
- Each subsequent time we run **make**, the dependencies will be re-created if necessary and the **echo** performed.

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Artificial Targets

We can take advantage of this trick by adding *artificial targets* that serve as the names for tasks to be performed.

```
build: codeAnnotation.jar

install: build
    cp codeAnnotation.jar $(INSTALLDIR)
```

clean:

```
rm *.class CppJavaScanner.java
```

codeAnnotation.jar: code2HTML.class CppJavaScanner.class

```
jar tvf codeAnnotation.jar code2HTML.class CppJavaScanner.class
```

CppJavaScanner.class: CppJavaScanner.java

```
javac CppJavaScanner.java
```

code2HTML.class: code2HTML.java CppJavaScanner.java

```
javac code2HTML.java
```

CppJavaScanner.java: code2html.flex

```
java -cp JFlex.jar JFlex.Main code2html.flex
```

.....

Common Artificial Targets

all Often made the first rule in the makefile so that it becomes the default. Builds everything. May also run tests.

build Build everything.

install Build, then install

test Build, then run tests

clean Delete everything that would have been produced by the makefile in a build or test run.

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3.3 Dependency Analysis

Dependency Analysis

Coming up with a list of dependencies (and keeping it current) can be troublesome.

- Various tools exist for this purpose for programming languages
- The **gcc** and **g++** compilers have a compile-time option, `-MMd`, which emits a `.d` file containing a target and dependency line.
 - Use this with an implicit rule to give the actual command

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Self-Building Makefile

```

MAINPROG=testpicture
CPPS:=$(wildcard *.cpp)
%
CPPFLAGS=-g -D$(DISTR)
CPP=g++
%
OBSJS=$(CPPS:%.cpp=%.o)
DEPENDENCIES = $(CPPS:%.cpp=%.d)

%.d: %.cpp
    touch $@

%.o: %.cpp

```

```
$(CPP) $(CPPFLAGS) -MMD -o $@ -c $*.cpp  
  
make.dep: $(DEPENDENCIES)  
-cat $(DEPENDENCIES) > $@  
  
include make.dep
```

- On the first **make**,
 - for each .cpp file, an empty .d file is created by **touch**
 - All *.d files are concatenated to form a file make.dep
 - The file make.dep is included as part of the makefile.
 - As the .cpp files are compiled, the .d files are replaced by a rule making the .o file dependent on that .cpp file and on any .h files that it included.
- On subsequent **make** runs,
 - the .d files contain the dependencies for each .cpp file.
 - All *.d files are concatenated to form a file make.dep
 - The file make.dep is included as part of the makefile.
 - If any .h or .cpp file has been changed, the .o files dependent on it will be regenerated.

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3.4 Managing Subproject Builds

Managing Subproject Builds

Subprojects are generally handled by giving each subproject its own makefile and usign a master makefile to invoke the artificial targets:

all:

```
cd model; make
cd vncurses; make
cd vcjava; make
```

clean:

```
cd model; make clean
cd vncurses; make clean
cd vcjava; make clean
```

.....

4 Case Studies:

4.1 C++ Spreadsheet Model

C++ Spreadsheet Model

```
MAINPROG=testssheet
CPPS=exprparser.cpp expr.cpp lexical.cpp exprfactory.cpp
expression.cpp cellrange.cpp clipboard.cpp
cellname.cpp numericnode.cpp stringnode.cpp cellrefnode.cpp
negatenode.cpp
plusnode.cpp
subtractnode.cpp timesnode.cpp dividesnode.cpp ifnode.cpp
```

```
    numvalue.cpp strvalue.cpp errvalue.cpp spreadsheet.cpp cell.cpp
    observable.cpp
    timenode.cpp timevalue.cpp
DIR=${PWD}
ASST=$(notdir ${DIR})
DISTR=Unix
EXE=.exe
LFLAGS=-L. -lssheet
#
#
#####
# Macro definitions for "standard" C and C++ compilations
#
CPPFLAGS=-g -fPIC -Wall -c
CFLAGS=-g
TARGET=libssheet.a
LINK=g++ $(LFLAGS)
#
CC=gcc
CPP=g++
#
#
# In most cases, you should not change anything below this line.
#
# The following is "boilerplate" to set up the standard compilation
# commands:
#
```

```
OBJS=$(CPPS:%.cpp=%.o)
DEPENDENCIES = $(CPPS:%.cpp=%.d)

%.d: %.cpp
    touch $@

%.o: %.cpp
    $(CPP) $(CPPFLAGS) -MMD -o $@ -c $*.cpp

#
# Targets:
#
all: $(TARGET) testssheet${EXE}

$(TARGET): $(OBJS)
    -rm $@
    ar -cvq $@ ${OBJS}

#    g++ -shared -Wl,-soname,$@ -o $@ ${OBJS}
```

```
tests: testcellname.out testssheet.out
```

```
testssheet.out: testssheet${EXE}  
  ./testssheet${EXE} ss1.dat > testssheet.out  
  ./testssheet${EXE} ss2.dat >> testssheet.out  
  ./testssheet${EXE} ss3.dat >> testssheet.out  
  ./testssheet${EXE} ss4.dat >> testssheet.out  
  ./testssheet${EXE} ss5.dat >> testssheet.out  
  ./testssheet${EXE} ss6.dat >> testssheet.out  
  diff testssheet.out testsheet.expected
```

```
test%.out: test%$(EXE)  
  ./test%${EXE} < test%*.dat > test%*.out  
  diff test%*.out test%*.expected
```

```
test%$(EXE): test%.o $(TARGET) unittest.o  
  g++ -o @$ test%*.o unittest.o -L. -lssheet
```

```
clean:  
  /bin/rm -f *.d *.a *.o *.exe $(TARGET)
```

```
lexical.cpp: lexical.l
```

```
flex -olexical.cpp lexical.l
expr.cpp: expr.y
bison -d -o expr.cpp expr.y

make.dep: $(DEPENDENCIES)
-cats $(DEPENDENCIES) > $@

include make.dep
```

.....

4.2 Assignments

Assignments

Setting up an assignment for a course:

```
include ../make.base
MAINPROG=testpicture
#
include ../cppMake.head

Tests/test%.out: Tests/test%.dat Work/${MAINPROG}
cd $(WORKDIR); /bin/sh ../Tests/test$.dat
mv $(WORKDIR)/test$.out $@
```

```
include ../cppMake.tail
```

- Note the heavy use of included files that standardize this process for multiple assignments over the same semester

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make.base

```
DIR=$PWD
ASST=$(notdir $DIR)
WINEXE=.exe
UNIXEXE=
ifneq (,$(findstring MinGW,$(PATH)))
DISTR=MinGW
EXE=$(WINEXE)
WORKDIR=winwork
else
DISTR=Linux
EXE=$(UNIXEXE)
WORKDIR=Work
endif
HTMLDIR=/home/zeil/cs330/webcourse/Assts/
INSTALLDIR=/home/zeil/cs330/Assignments/$(ASST)
```

.....

cppmake.head

```
#
PUBLICFILESx=$(wildcard Public/*)
PUBLICFILES=$(filter-out %~, ${PUBLICFILESx})
PUBLIC=$(notdir ${PUBLICFILES})
SOLUTIONFILES=$(wildcard Solution/*.h) $(wildcard Solution/*.cpp)
TESTDATFILES=$(wildcard Tests/test*.dat)
TESTDAT=$(notdir ${TESTDATFILES})
TESTOUTFILES=$(TESTDATFILES:%.dat=%.out)
SOLUTIONTESTDAT=$(TESTDAT:%.dat=Solution/%.dat)
SOLUTIONTESTOUT=$(TESTDAT:%.dat=Solution/%.out)
INSTALLEDFILES=$(PUBLIC:%=${INSTALLDIR}/%)
WORKMAIN=Work/${MAINPROG}
#
all: Work/${MAINPROG} ${TESTOUTFILES} ${SOLUTIONTESTDAT} ${SOLUTIONTESTOUT}
```

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cppmake.tail

```
#
Solution/%.dat: Tests/%.dat
    -rm Solution/$*.dat
    cd Solution; ln ../Tests/$*.dat
Solution/%.out: Tests/%.out
```



```
-rm Solution/*.out  
cd Solution; ln ../Tests/*.out
```

```
Work/$(MAINPROG): ${PUBLICFILES} ${SOLUTIONFILES}  
mkdir -p Work  
cp ${PUBLICFILES} Work  
cp ${SOLUTIONFILES} Work  
touch Work/make.dep  
cd Work; make
```

```
WinWork/$(MAINPROG).exe: ${PUBLICFILES} ${SOLUTIONFILES}  
mkdir -p WinWork  
cp ${PUBLICFILES} WinWork  
cp ${SOLUTIONFILES} WinWork  
touch WinWork/make.dep  
cd WinWork; make CPP=i586-mingw32msvc-g++ LINK=i586-mingw32msvc-g++ LFLAGS=-lm  
/bin/mv WinWork/$(MAINPROG) @$
```

```
install: ${HTMLDIR}/${ASST}.html  
${INSTALLDIR}/bin/Linux/$(MAINPROG)  
${INSTALLDIR}/bin/Windows/$(MAINPROG).exe  
${INSTALLEDFILES}  
${SOLUTIONTESTDAT} ${SOLUTIONTESTOUT}  
find ${INSTALLDIR} -type f -exec chmod 664 {} ;  
find ${INSTALLDIR} -type d -exec chmod 775 {} ;  
-chmod 775 ${INSTALLDIR}/bin/*/*
```

```

${HTMLEDIR}/${ASST}.html: ${ASST}.html
    cp ${ASST}.html ${HTMLEDIR}

${INSTALLDIR}/bin/Linux/${MAINPROG}: Work/${MAINPROG} ${INSTALLDIR}
    mkdir -p ${INSTALLDIR}/bin/Linux
    -cp Work/${MAINPROG} ${INSTALLDIR}/bin/Linux/

${INSTALLDIR}/bin/Windows/${MAINPROG}.exe: WinWork/${MAINPROG}.exe ${INSTALLDIR}
    mkdir -p ${INSTALLDIR}/bin/Windows
    -cp WinWork/${MAINPROG}.exe ${INSTALLDIR}/bin/Windows/

${INSTALLDIR}/%: Public/% ${INSTALLDIR}
    cp Public/%* ${INSTALLDIR}

${INSTALLDIR}:
    -mkdir -p $@

clean:
    -rm -rf Work/* ${SOLUTIONTESTDAT} ${SOLUTIONTESTOUT} ${TESTOUTFILES}

cleaner:
    -rm Work/* ${SOLUTIONTESTDAT} ${SOLUTIONTESTOUT} ${TESTOUTFILES}
    -rm ${HTMLEDIR}/${ASST}.html
    -rm -rf ${INSTALLDIR}
```





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