Managing recompilation

- What happens if a source file is changed?
  - Possibly need to recompile all the files that referenced it
- How to do this?
  - IDE: built-in
  - So far: by hand
    - Call `javac` on out-of-date source files, maybe re-`jar`
    - But: tedious, error prone
  - Tool-based approach: make a tool for it!

make

- `make` is a great tool that manages any kind of process with dependencies
- A `Makefile` describes rules for when something depends on something else, and what to do to make it up-to-date
  - based on file modification times stored with every Unix file
- Invoking `make` then runs these rules to decide what, if anything, needs to be done to bring things up-to-date

Dependencies

- `Makefile` includes lines of the form

  target… : *source*…
  - Means that each target *depends on* each source
  - If any of the sources are modified, then all the targets are considered out-of-date
- Example:

```
main.class: main.java
```

Actions

- For each dependency, can add an action to perform to bring the target(s) up-to-date
  - Action is a series of shell command lines
    - each line must start with a tab
    - use /bin/sh syntax
- Example:

```
main.class: main.java
        javac main.java
```

Invoking make

- `make` *target*…
  - uses `Makefile` in current directory to bring one or more *target*s up to date, using their actions
  - does nothing if all targets up to date
  - if omit target arguments, then rebuild the first target in Makefile
    - the default target
- Example:

```
> make main.class
javac main.java
>
```

Controlling output

- By default, `make` prints out each action it performs
- Can disable printing an action by prefixing it with @
- Example:

```
main.class: main.java
        @echo Compiling main.java…
        @javac main.java
> make main.class
Compiling main.java…
>
```

Dependency patterns

- Often have a simple rule over all files with certain naming patterns
  - Can use `%` in the target and source
  - Rule applies to any real targets and sources where `%` is replaced by the same thing on both sides
- Example:

```
%.class: %.java
```

  - Means that *X*`.class` depends on *X*`.java`

Actions for patterns

- Actions for dependency patterns need to have patterns too
  - `$@`: the target
  - `$^`: the source(s)
  - `$*`: the thing matched by `%` in the rule
- Example:

```
%.class: %.java
        @echo –n "compiling class $* "
        @echo "($^ to $@)"
        javac $^
```

Dependency trees

- One target can depend on another target, ad nauseum
  - Dependency rules form a *DAG* (directed acyclic graph)
- `make` figures out how to rebuild a target by first making sure its sources are up-to-date, which may cause `make` to first rebuild them, recursively

Example dependency tree

```
%.class: %.java
        javac $^
main.jar: main.class helper.class
        jar cfv $@ $^
install: main.jar
        cp $^ ${HOME}/bin

> make install
javac main.java
javac helper.java
jar cfv main.jar main.class helper.class
cp main.jar /homes/iws/myLogin/bin
```

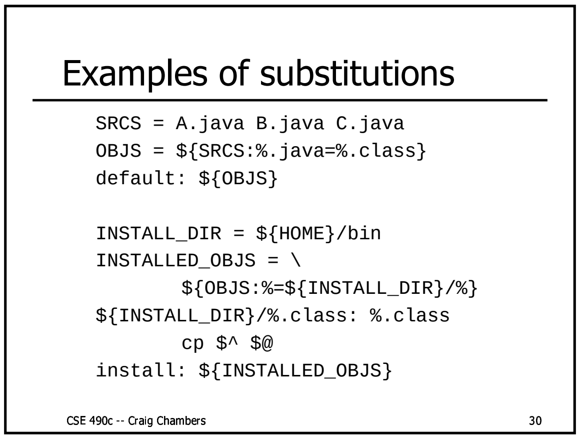
Makefile variables

- Can define variables in `Makefiles`, and use them in rules and actions
  - *VARNAME* = *REPLACEMENT*...
  - Referenced using `${`*VARNAME*`}`
- Example:

```
JAVAC_FLAGS = -g
%.class: %.java
      @echo "compiling class $*"
      javac ${JAVAC_FLAGS} $^
```

Substitutions in make vars

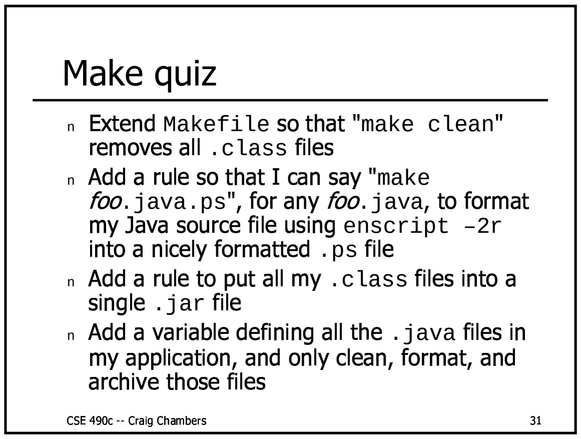
- Can do replacements in variables
  - `${`*VAR*: *oldPat*=*newPat*`}`
  - *oldPat* and *newPat* can contain `%`
  - match each word in `${`*VAR*`}` against *oldPat*, where `%` can match anything
  - replace matches with *new*
    - if *new* contains `%`, substitute with what `%` matched
- Good for adjusting extensions, prefixes



Examples of substitutions

```
SRCS = A.java B.java C.java
OBJS = ${SRCS:%.java=%.class}
default: ${OBJS}

INSTALL_DIR = ${HOME}/bin
INSTALLED_OBJS = \
        ${OBJS:%=${INSTALL_DIR}/%}
${INSTALL_DIR}/%.class: %.class
        cp $^ $@
install: ${INSTALLED_OBJS}
```



Make quiz

- Extend `Makefile` so that "`make clean`" removes all `.class` files
- Add a rule so that I can say "`make` *foo*`.java.ps`", for any *foo*`.java`, to format my Java source file using `enscript -2r` into a nicely formatted `.ps` file
- Add a rule to put all my `.class` files into a single `.jar` file
- Add a variable defining all the `.java` files in my application, and only clean, format, and archive those files