Advanced Programming Techniques

Shell Scripting
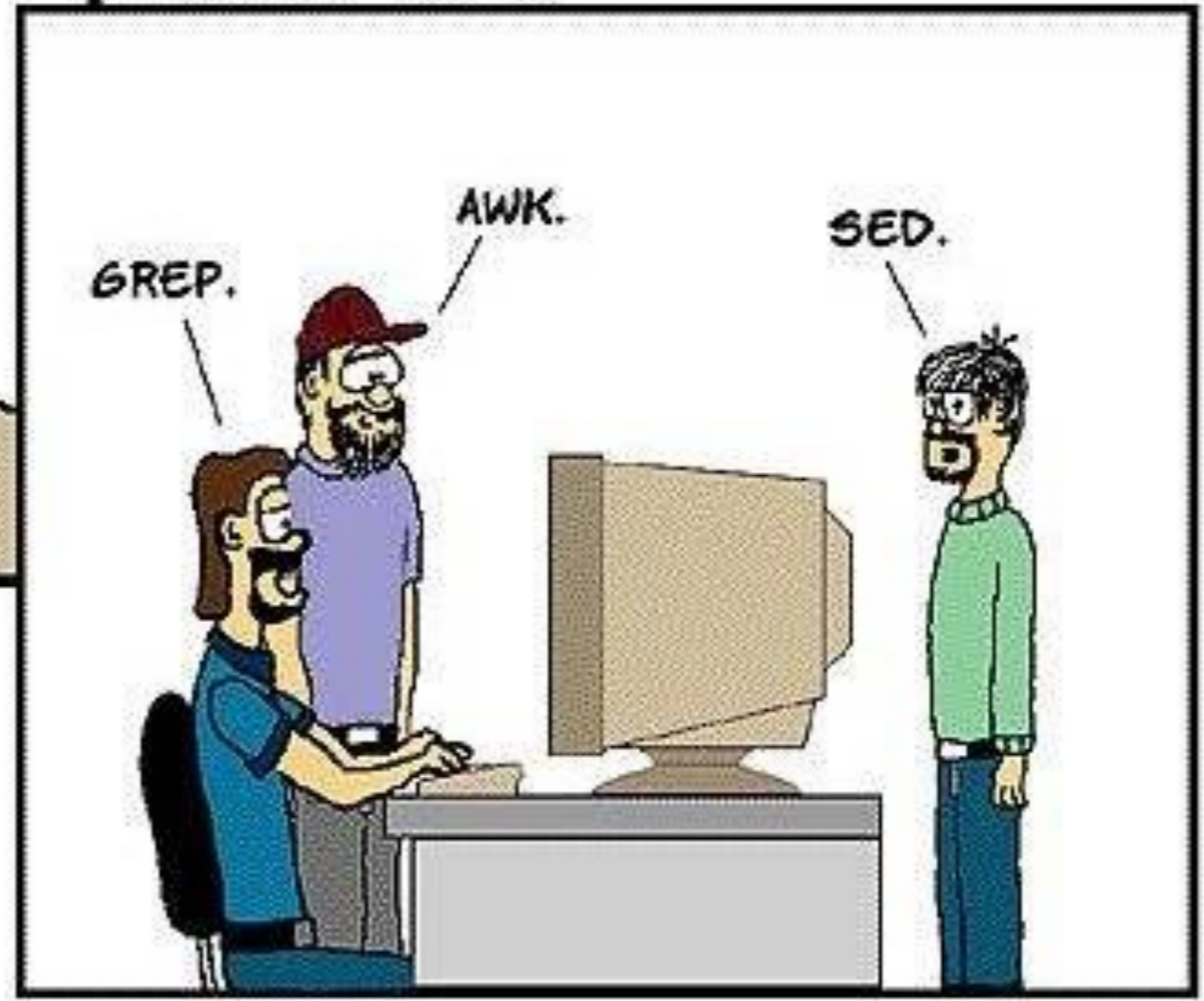
Christopher Moretti
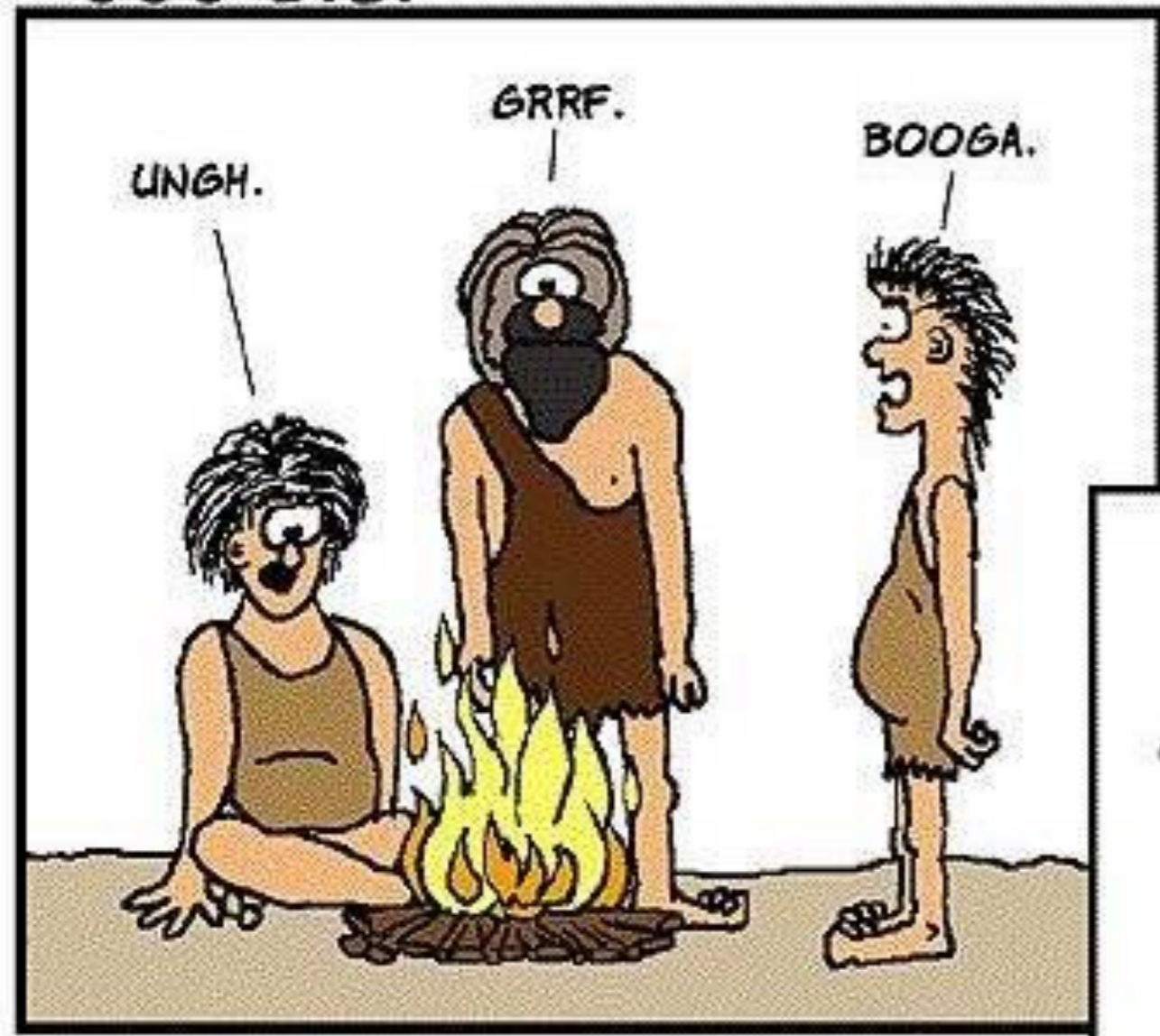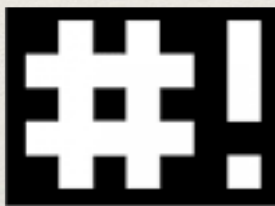
Scripting Languages

- Scripting **is** programming!

  - factors of engineering, design, efficiency, etc.

- Focus on the right tool for the right task

- Automate execution of tasks, control other programs

  - rapid prototyping

  - "glue" code

  - quick hacks? large-scale programs?

"Scripting is a lot like obscenity.
I can't define it, but I'll know it when I see it."

–Larry Wall

Scripting Characteristics

- strings as basic (or only) type

- regular expressions as a built-in

- associative arrays as a built-in

- implicit types, declarations, etc.

- automatic garbage collection

- usually interpreted

- mostly imperative; with some functional ideas (though this is changing towards beefier OOP)
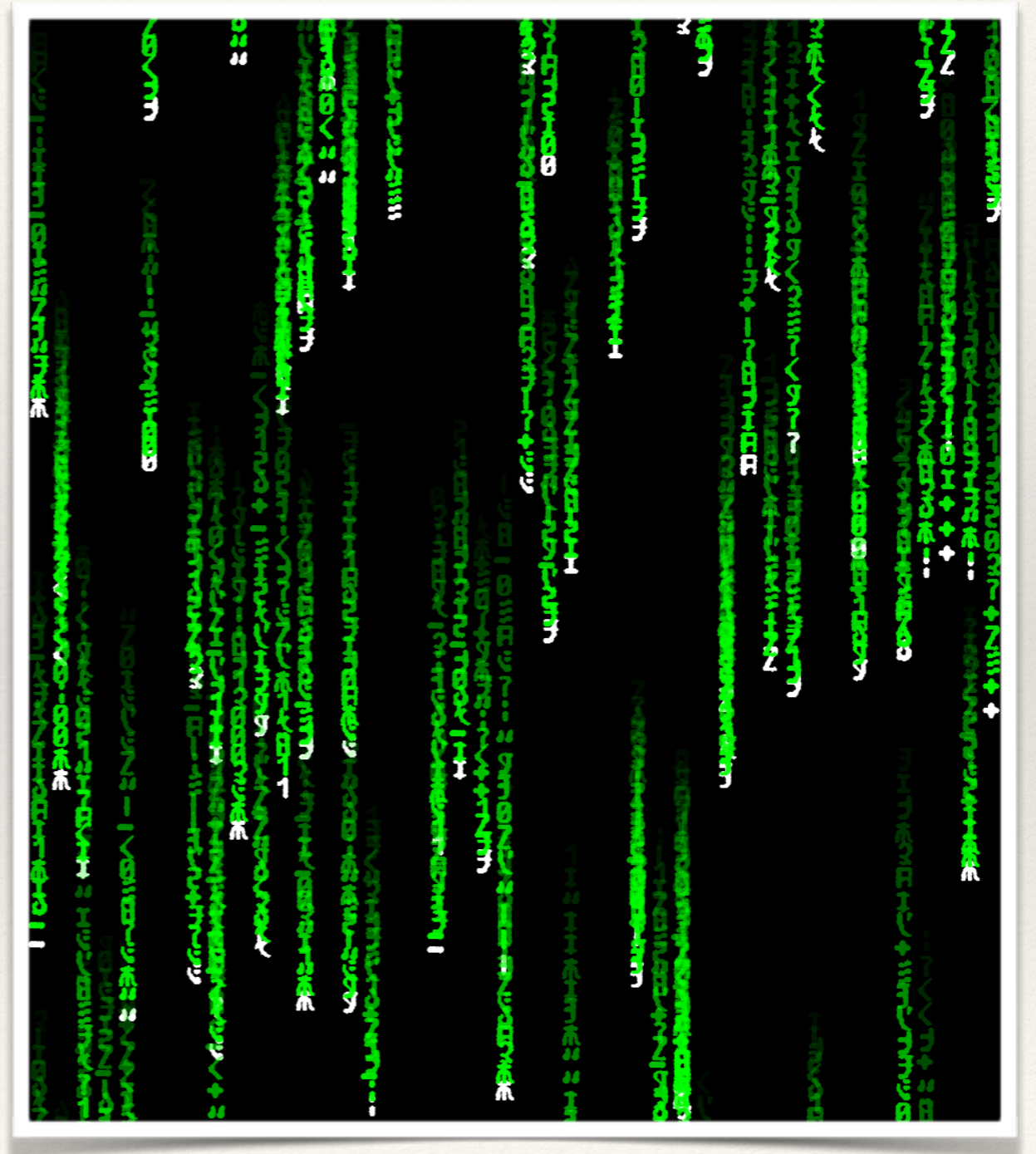
^ not actually what scripting looks like

Shells

❖ Shell - a program to run other programs

❖ We often talk of "The Shell", but it's just a program … there are options

   ❖ sh   Bourne shell (Steve Bourne, Cambridge -> Bell Labs -> … -> VC land)

   ❖ csh   C shell   (Bill Joy, Berkeley -> Sun -> VC land)

   ❖ ksh   Korn shell (David Korn, NYU -> Bell Labs -> AT&T Labs -> Google)

   ❖ bash   GNU shell (Brian Fox, MIT -> FSF -> serial entrepreneur)

   ❖ tcsh   Ken Greer (CMU -> Bell -> HP -> entrepreneur)

   ❖ zsh Paul Falstad '92 (developed in 1990 - hey '18s, what are YOU doing?)

Shell Scripting

- "Program-based" programming

  - gluing together existing tools to make new ones

- Often good for personal tools, comfort

  - tailoring environment, easing common workflows

- Quick and dirty sometimes wins

  - but that isn't to say you can't do software engineering

  - out of style for large-scale production, but not impossible

Common Shell Script Features

- ❖ Command execution of programs and built-ins

- ❖ Redirection and piping of input, output

- ❖ Filename expansion / globbing with * ? []

- ❖ Meaningful quoting, e.g. difference between " ' `

- ❖ Manipulation of environment variables

- ❖ Executable commands from a file

"Language shapes the way we think and determines what we can think about"

– Benjamin Whorf (1897-1941)

American linguist

"A programming language that doesn't change the way you think is not worth learning."

–Alan Perlis (1922-1990)

Inaugural Turing Award winner

1986 CACM Programming Pearls

- The "challenge" was intended to show off the virtues of "Literate Programming"

- The two players were Don Knuth and Doug McIlroy

- Given a text file and an integer k, print the k most common words in the file (and the number of their occurrences) in decreasing frequency.

p	link [p]	ch [p]	sibling [p]	count [p]	Word
0	0	header	26		
1	2014	1	0		a
2	1000	2	1		b
3		3	2		c
⋮					
1000	2	header	1005		
1001					
1002					
1003					
1004					
1005	2000	5	1000		be
⋮					
2000	1005	header	2021		
⋮					
2014	1	header	2020		
2015	3000	15	2000		ben
2016					
2017					
2018					
2019					
2020	4000	6	2014		af
2021		20	2015		bet

1986 CACM Programming Pearls

- "Very few people can obtain the virtuoso services of Knuth … [b]ut old Unix hands know instinctively how to solve this one in a jiffy."

- Concern about space usage, as Knuth's version was stateful

```
(1) tr -cs A-Za-z'
    ' |
(2) tr A-Z a-z |
(3) sort |
(4) uniq -c |
(5) sort -rn |
(6) sed ${1}q
```

Moby Dick
Herman Melville

Call me Ishmael. Some years ago- never mind how long precisely- having little or no money in my purse, and nothing particular to interest me on shore, I thought I would sail about a little and see the watery part of the world. It is a way I have of driving off the spleen and regulating the circulation. Whenever I find myself growing grim about the mouth; whenever it is a damp, drizzly November in my soul; whenever I find myself involuntarily pausing before coffin warehouses, and bringing up the rear of every funeral I meet; and especially whenever my hypos get such an upper hand of me, that it requires a strong moral principle to prevent me from deliberately stepping into the street, and methodically knocking people's hats off- then, I account it high time to get to sea as soon as I can. This is my substitute for pistol and ball. With a philosophical flourish Cato throws himself upon his sword; I quietly take to the ship. There is nothing surprising in this. If they but knew it, almost all men in their degree, some time or other, cherish very nearly the same feelings towards the ocean with me.

There now is your insular city of the Manhattoes, belted round by wharves as Indian isles by coral reefs- commerce surrounds it with her surf. Right and left, the streets take you waterward. Its extreme downtown is the battery, where that noble mole is washed by waves, and cooled by breezes, which a few hours previous were out of sight of land. Look at the crowds of water-gazers there.

```
tr -cs [:alpha:] '\n'
```

Moby
Dick
Herman
Melville
Call
me
Ishmael
Some
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ago
never
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spleen

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regulating
the
circulation
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I
find
myself
growing
grim
about
the
mouth
whenever
it
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damp
drizzly
November
in
my
soul
whenever
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find
myself
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pausing
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`tr [:upper:] [:lower:]`

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melville
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`uniq -c`

6 a
2 about
1 account
1 ago
1 all
1 almost
1 an
9 and
3 as
1 at
1 ball
1 battery
1 before
1 belted
1 breezes
1 bringing
1 but
4 by
1 call
1 can
1 cato
1 cherish
1 circulation
1 city
1 coffin
1 commerce
1 cooled
1 coral
1 crowds
1 damp
1 degree
1 deliberately
1 dick
1 downtown
1 driving
1 drizzly
1 especially
1 every
1 extreme
1 feelings
1 few
2 find
1 flourish
1 for
1 from
1 funeral
1 gazers
2 get
1 grim
1 growing
1 hand
1 hats
1 have
1 having
1 her
1 herman
1 high
1 himself

1 his
1 hours
1 how
1 hypos
9 i
1 if
4 in
1 indian
1 insular
1 interest
1 into
1 involuntarily
7 is
1 ishmael
1 isles
6 it
1 its
1 knew
1 knocking
1 land
1 left
2 little
1 long
1 look
1 manhattoes
5 me
1 meet
1 melville
1 men
1 methodically
1 mind
1 moby
1 mole
1 money
1 moral
1 mouth
4 my
2 myself
1 nearly
1 never
1 no
1 noble
2 nothing
1 november
1 now
1 ocean
8 of
2 off
1 on
2 or
1 other
1 out
1 part
1 particular
1 pausing
1 people
1 philosophical
1 pistol

1 precisely
1 prevent
1 previous
1 principle
1 purse
1 quietly
1 rear
1 reefs
1 regulating
1 requires
1 right
1 round
1 s
1 sail
1 same
1 sea
1 see
1 ship
1 shore
1 sight
2 some
1 soon
1 soul
1 spleen
1 stepping
1 street
1 streets
1 strong
1 substitute
1 such
1 surf
1 surprising
1 surrounds
1 sword
2 take
2 that
14 the
1 their
1 then
3 there
1 they
2 this
1 thought
1 throws
2 time
5 to
1 towards
1 up
1 upon
1 upper
1 very
1 warehouses
1 washed
1 water
1 waterward
1 watery
1 waves
1 way

1 were
1 wharves
4 whenever
1 where
1 which
3 with
1 world
1 would
1 years
1 you
1 your

sort -rn

14 the	1 surf	1 long	1 breezes
9 i	1 such	1 left	1 belted
9 and	1 substitute	1 land	1 before
8 of	1 strong	1 knocking	1 battery
7 is	1 streets	1 knew	1 ball
6 it	1 street	1 its	1 at
6 a	1 stepping	1 isles	1 an
5 to	1 spleen	1 ishmael	1 almost
5 me	1 soul	1 involuntarily	1 all
4 whenever	1 soon	1 into	1 ago
4 my	1 sight	1 interest	1 account
4 in	1 shore	1 insular	
4 by	1 ship	1 indian	
3 with	1 see	1 if	
3 there	1 sea	1 hypos	
3 as	1 same	1 how	
2 time	1 sail	1 hours	
2 this	1 s	1 his	
2 that	1 round	1 himself	
2 take	1 right	1 high	
2 some	1 requires	1 herman	
2 or	1 regulating	1 her	
2 off	1 reefs	1 having	
2 nothing	1 rear	1 have	
2 myself	1 quietly	1 hats	
2 little	1 purse	1 hand	
2 get	1 principle	1 growing	
2 find	1 previous	1 grim	
2 about	1 prevent	1 gazers	
1 your	1 precisely	1 funeral	
1 you	1 pistol	1 from	
1 years	1 philosophical	1 for	
1 would	1 people	1 flourish	
1 world	1 pausing	1 few	
1 which	1 particular	1 feelings	
1 where	1 part	1 extreme	
1 wharves	1 out	1 every	
1 were	1 other	1 especially	
1 way	1 on	1 drizzly	
1 waves	1 ocean	1 driving	
1 watery	1 now	1 downtown	
1 waterward	1 november	1 dick	
1 water	1 noble	1 deliberately	
1 washed	1 no	1 degree	
1 warehouses	1 never	1 damp	
1 very	1 nearly	1 crowds	
1 upper	1 mouth	1 coral	
1 upon	1 moral	1 cooled	
1 up	1 money	1 commerce	
1 towards	1 mole	1 coffin	
1 throws	1 moby	1 city	
1 thought	1 mind	1 circulation	
1 they	1 methodically	1 cherish	
1 then	1 men	1 cato	
1 their	1 melville	1 can	
1 sword	1 meet	1 call	
1 surrounds	1 manhattoes	1 but	
1 surprising	1 look	1 bringing	

14 the
9 i
9 and
8 of
7 is
6 it
6 a
5 to
5 me
4 whenever

sed 10q

```
... | sed 100q
13967 the      770 now     426 ship    288 great
6415 of        761 had     421 ye      288 boat
6247 and       747 have    418 would   287 has
4583 a         681 or      408 been    281 seemed
4508 to        672 were    400 over    280 white
4037 in        638 they    393 these   278 must
2911 that      634 like    393 other   274 most
2481 his       623 me      383 though
2370 it        620 which   375 will
1940 i         615 then    371 down
1793 but       606 some    365 such
1743 he        603 their   363 only
1709 as        595 when    356 whales
1680 with      588 an      343 yet
1674 is        586 are     336 who
1600 was       577 my      333 head
1580 for       575 no      331 time
1508 all       552 upon    330 long
1368 this      548 what    328 her
1295 at        527 out     322 any
1158 by        511 into    317 very
1136 not       504 up      309 still
1064 from      501 more    306 captain
1044 so        473 man     305 about
1044 him       469 its     301 do
1031 on        469 if      299 those
1024 be        463 them    299 than
1017 whale     447 old     297 said
 886 one       432 ahab    293 before
 845 you       430 sea     292 here
 777 there     428 we      291 two
```

Today, this is the canonical example of Map-Reduce

bash

Simple Commands

❖ types: executables, built-ins, keywords, aliases, functions

❖ Most of your favorite *nix commands are stand-alone executables, which can be executed as part of a script

  ❖ grep, lpr, ls, sed, touch, etc.

  ❖ bash looks for executables in the directories in $PATH

❖ built-ins are commands implemented inside bash

❖ keywords are the reserved words of language

❖ aliases are textual shortcuts

Simple Commands

❖ types: executables, built-ins, keywords, aliases, functions

❖ Most of your favorite *nix commands are stand-alone executables, which can be executed as part of a script

❖ built-ins are commands implemented inside bash

　❖ alias, bg, cd, echo, exit, fg, printf, where, which

❖ keywords are the reserved words of language

❖ aliases are textual shortcuts

Simple Commands

- ❖ types: executables, built-ins, keywords, aliases, functions

- ❖ Most of your favorite *nix commands are stand-alone executables, which can be executed as part of a script

- ❖ built-ins are commands implemented inside bash

- ❖ keywords are the reserved words of language

  - ❖ do/done, for/in, if/then/else/fi, while/until

- ❖ aliases are textual shortcuts

Simple Commands

❖ types: executables, built-ins, keywords, aliases, functions

❖ Most of your favorite *nix commands are stand-alone executables, which can be executed as part of a script

❖ built-ins are commands implemented inside bash

❖ keywords are the reserved words of language

❖ aliases are textual shortcuts: only for interactive shells

  ❖ alias rm='rm -i'

  ❖ alias 333='ssh -X cos333@penguins.cs.princeton.edu'

Your First bash Script

```
#!/bin/bash

echo "Hello, World!"
```

```
$bash helloworld.sh
Hello, World!
$./helloworld.sh
-bash: ./helloworld.sh: Permission denied
$ls -l helloworld.sh
-rw-r--r--  1 cmoretti  staff  34 Feb  9 04:09 helloworld.sh
$chmod u+x helloworld.sh
$ls -l helloworld.sh
-rwxr--r--  1 cmoretti  staff  34 Feb  9 04:09 helloworld.sh
$./helloworld.sh
Hello, World!
$chmod 755 helloworld.sh
$ls -l helloworld.sh
-rwxr-xr-x  1 cmoretti  staff  34 Feb  9 04:09 helloworld.sh
```

Simple Variables

```
#!/bin/bash

message="Hello, World!"
echo $message
```

```
$./helloworld.sh
Hello, World!
```

```
#!/bin/bash

number=42
echo $number
```

```
$./meaning.sh
42
```

Variable Expansion

```
#!/bin/bash

file="bad name.txt"
rm "$file"
```

```
#!/bin/bash

file="bad name.txt"
rm $file
```

```
$touch "bad name.txt"
$ls ./bad\ name.txt
./bad name.txt
$./bad.sh
```

```
$touch "bad name.txt"
$ls ./bad\ name.txt
./bad name.txt
$./bad.sh
rm: bad: No such file or directory
rm: name.txt: No such file or directory
```

Variable Pattern Expansion

```bash
#!/bin/bash

echo 0 $noval
echo 1 ${noval:-foo.txt}
echo 2 $noval
echo 3 ${#noval}

echo 4 $noval
echo 5 ${noval:=foo.txt}
echo 6 $noval
echo 7 ${#noval}

echo 8 ${noval:0:3}
echo 9 ${noval:(-3):3}

echo A ${noval#*o}
echo B ${noval##*o}
echo C ${noval%*.txt}
echo D ${noval%%.*}
```

```
$./expand.sh
0
1 foo.txt
2
3 0


4
5 foo.txt
6 foo.txt
7 7


8 foo
9 txt


A o.txt
B .txt
C foo
D foo
```

Special Variables (Parameters)

- `$0`   program name
- `$#`   number of args
- `$1 - $#`   names of args
- `$*`   all the args
- `$?`   exit status of last command
- `$RANDOM`   random number 0-32k
- `$$`   current process PID

Special (Meta-) Characters

- `" "`   don't split text

- `' '`   don't split text, don't interpret

- `` ` ` ``   execute this program, return stdout

- `\`   escape character

- `(( ))`   allow for arithmetic

- `( )`   run in a subshell

- `< > |`   input, output, piped redirection

Your First "Special" Program

```bash
#!/bin/bash

echo "I am $0 : $$"
echo "I have $# args"
echo "They are: $*"
echo "First   : $1"
echo "Second  : $2"
echo "Third   : $3"
echo "$RANDOM $RANDOM $RANDOM"
true ; echo $?
false ; echo $?
echo "exit 17" | bash; echo $?
echo "exit -1" | bash; echo $?
files=`ls -1 .`
echo '$files':\""$files"\" $((12+30))
(echo -n "sub "; exit 23); echo $?
```

```
$./specials.sh one two
I am ./specials.sh : 47662
I have 2 args
They are: one two
First   : one
Second  : two
Third   :
15425 27 25380
0
1
17
255

$files:"specials.sh
expand.sh" 42
sub 23
```

Array Variables

```bash
#!/bin/bash

declare -a array #optional
array[0]="zero"
array[200]=200
keys=${!array[*]}
vals=${array[*]}
echo $keys
echo $vals
array=(16 "three" i $vals)
echo ${#array[*]} items
echo ${array[*]}
```

```bash
#!/bin/bash

declare -A array #mandatory
array[0]="zero"
array["foo"]=200
keys=${!array[@]}
echo $keys
vals=${array[*]}
echo $vals
array["foo"]=$((array["foo"]*2))
foo="foo"
echo ${array[$foo]}
```

```
$./arrays.sh
0 200
zero 200
5 items
16 three i zero 200
```

```
$ ./hashes.sh
foo 0
200 zero
400
```

Globs and Braces

- Globs are a limited form of regular expressions

  - implicitly anchored on both ends

  - `*`   any string, including the null string

  - `?`   any single character

  - `[rst]`   any single character from the set

- Brace expansion is a limited form of enumeration

  - `ls *.{jpg,jpeg,JPG,JPEG}`

  - `ls file{0,1}{0..9}`

Control Flow – Conditionals

- Exit status control flow with short-circuiting: `&&` , `||`
  - `false && echo "will not print"`
  - `true || echo "will not print"`
  - `true && echo "prints"`
  - `false || echo "prints"`
- Conditionals: `if then else fi`
- Testing: `test [ [[`

Control Flow – Conditionals

- Exit status control flow with short-circuiting: `&&` , `||`

- Conditionals: `if then elif else fi`

  - `if true; then echo "t" else echo "f"; fi`

  - `if (($x<17)); then echo "small"; elif (($x>17)); then echo "big"; else echo "equal"; fi`

- Testing: `test [ [[`

Control Flow – Conditionals

- Exit status control flow with short-circuiting: `&&`, `||`

- Conditionals: `if then elif else fi`

- Testing: `test [ [[`

  - `test "a" = "a"; echo $?`   `0`

  - `test "a" = "b"; echo $?`   `1`

  - `if [[ $file = *.png ]]; then`
    `echo "picture"; else echo "text"; fi`

  - `if [[ $file =~ '.txt' ]]; then`
    `echo "text"; else echo "nontext"; fi`

  - `numerous tags for file properties, comparisons`

Control Flow – Loops

❖ The same loops you've come to expect

  ❖ `while true; do echo "infinite"; done`

  ❖ `while (($i<5)); do echo $((i++)); done`

  ❖ `for((i=0 ; i<5 ;i++)); do echo $i; done`

❖ And some you might not have seen:

  ❖ `for i in {0..4}; do echo $i; done`

  ❖ `for file in *; do echo $file; done`

Takeaways

- The shell was among the earliest scripting languages

- Still hugely useful for simple scripts

  - And sometimes that's all you need

- Shell programming fell out of favor

  - Limited feature set without writing other programs

  - Potentially slow

  - Quoting is a mess!

- This leads to non-shell scripting languages …