Lecture 5

sed and **awk**

Last week

- Regular Expressions
  - grep
  - egrep

Today

- Stream manipulation:
  - **sed**
  - **awk**

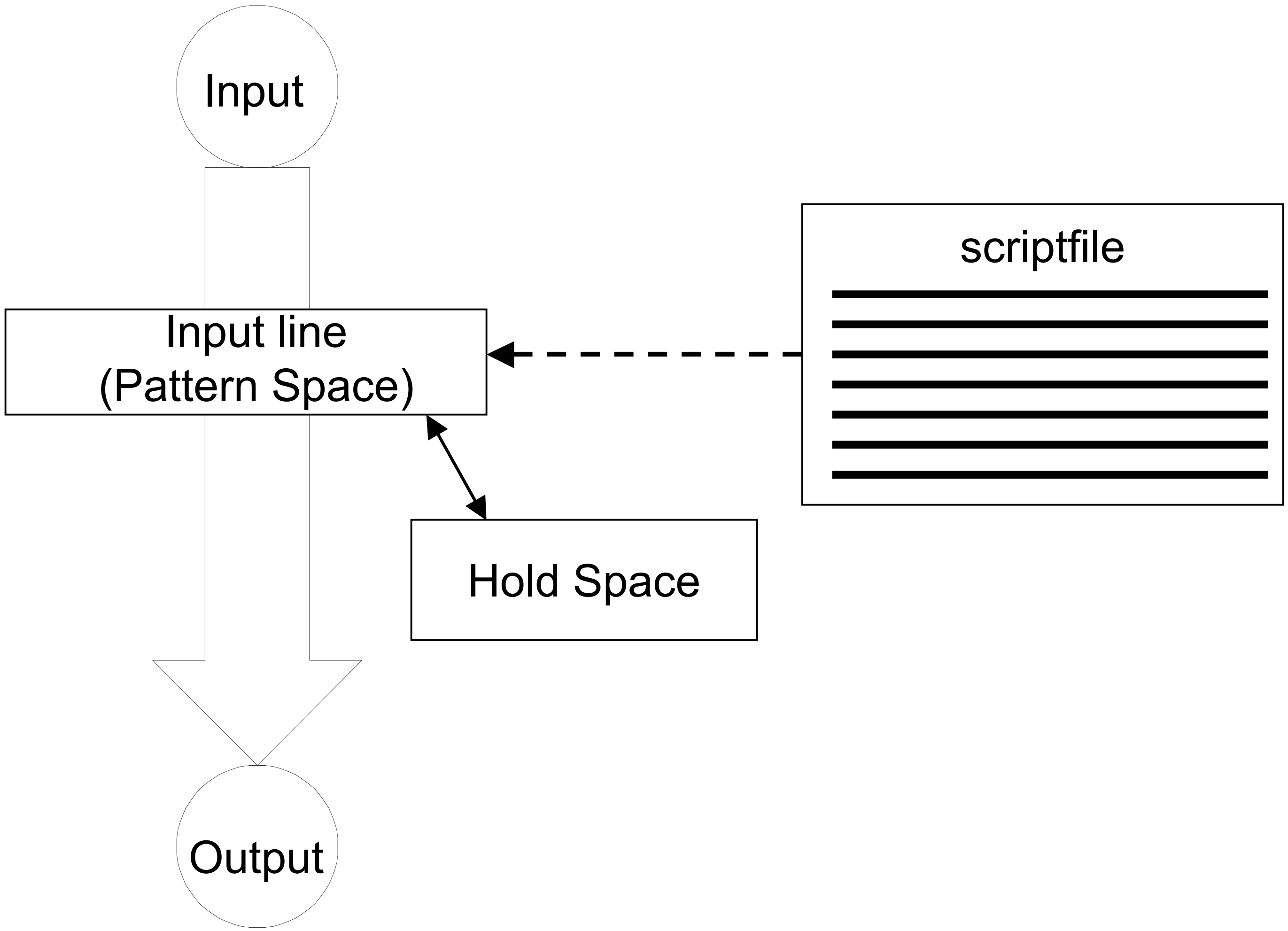
Sed: Stream-oriented, Non-Interactive, Text Editor

- Look for patterns one line at a time, like **grep**
- *Change* lines of the file
- Non-interactive text editor
  - Editing commands come in as *script*
  - There is an interactive editor *ed* which accepts the same commands
- A Unix filter
  - Superset of previously mentioned tools

Conceptual overview

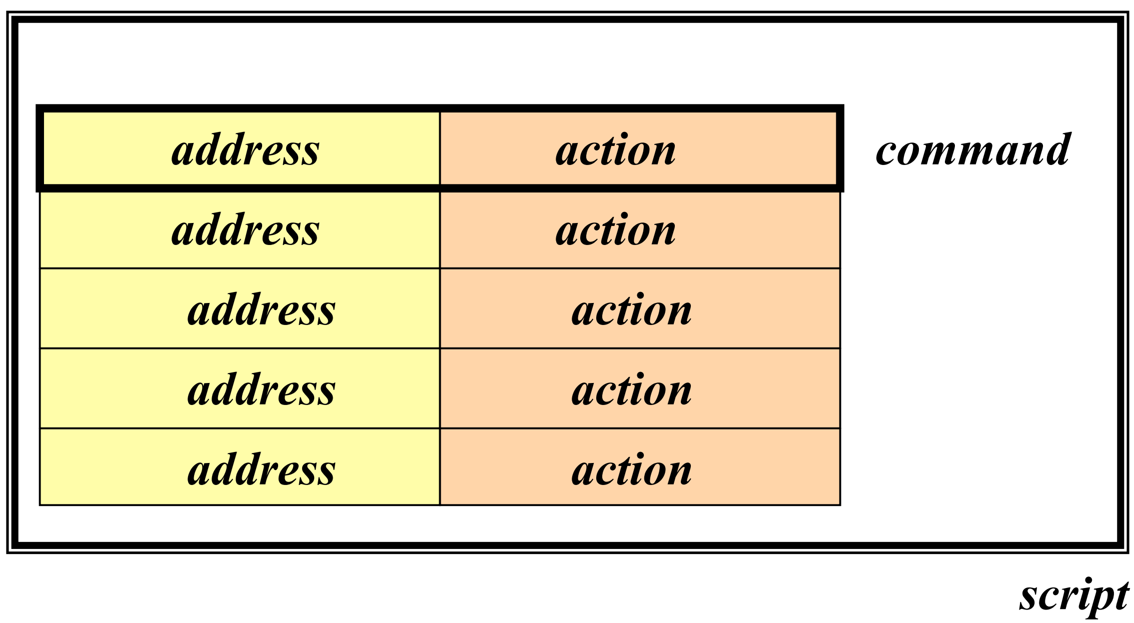
- All editing commands in a **sed** script are applied in order to each input line.
- If a command changes the input, subsequent command address will be applied to the current (modified) line in the pattern space, not the original input line.
- The original input file is unchanged (sed is a filter), and the results are sent to standard output (but can be redirected to a file).

Sed Architecture



Scripts

- A script is nothing more than a file of commands
- Each command consists of up to two *addresses* and an *action*, where the *address* can be a regular expression or line number.

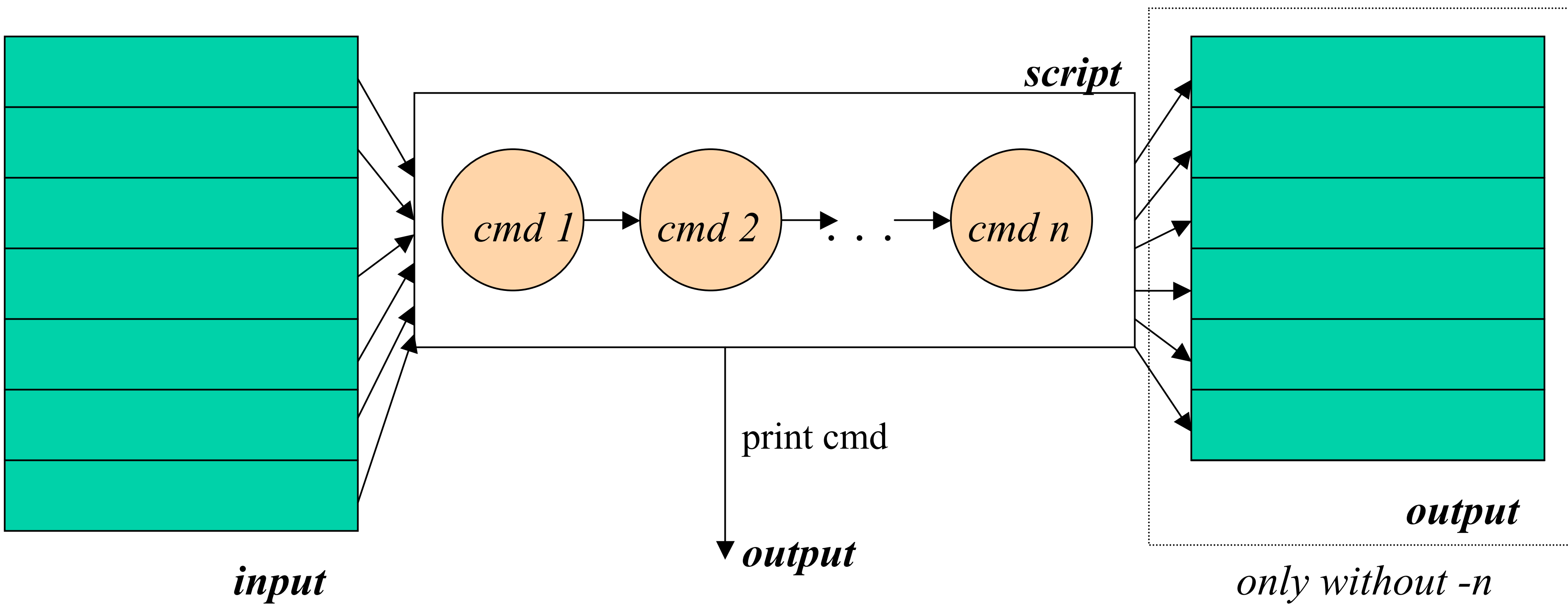


Scripts (continued)

- As each line of the input file is read, *sed* reads the first command of the script and checks the *address* against the current input line:
  - If there is a match, the command is executed
  - If there is no match, the command is ignored
  - *sed* then repeats this action for every command in the script file
- When it has reached the end of the script, *sed* outputs the current line (pattern space) unless the *-n* option has been set

Sed Flow of Control

- *sed* then reads the next line in the input file and restarts from the beginning of the script file
- All commands in the script file are compared to, and potentially act on, all lines in the input file



sed Commands

- sed commands have the general form
  - *[address[, address]][!]command [arguments]*
- *sed* copies each input line into a *pattern space*
  - If the address of the command matches the line in the *pattern space*, the command is applied to that line
  - If the command has no address, it is applied to each line as it enters *pattern space*
  - If a command changes the line in *pattern space*, subsequent commands operate on the modified line
- When all commands have been read, the line in *pattern space* is written to standard output and a new line is read into *pattern space*

Addressing

- An address can be either a line number or a pattern, enclosed in slashes (/*pattern*/)
- A pattern is described using *regular expressions* (BREs, as in **grep**)
- If no pattern is specified, the command will be applied to **all** lines of the input file
- To refer to the last line: **$**

Addressing (continued)

- Most commands will accept two addresses
  - If only one address is given, the command operates only on that line
  - If two comma separated addresses are given, then the command operates on a range of lines between the first and second address, inclusively
- The `!` operator can be used to negate an address, ie; *address!command* causes *command* to be applied to all lines that do ***not*** match *address*

Commands

- *command* is a single letter
- Example: Deletion: **`d`**
- **`[address1][,address2]d`**
  - Delete the addressed line(s) from the pattern space; line(s) not passed to standard output.
  - A new line of input is read and editing resumes with the first command of the script.

Address and Command Examples

- `d` deletes the all lines
- `6d` deletes line 6
- `/^$/d` deletes all blank lines
- `1,10d` deletes lines 1 through 10
- `1,/^$/d` deletes from line 1 through the first blank line
- `/^$/,$d` deletes from the first blank line through the last line of the file
- `/^$/,10d` deletes from the first blank line through line 10
- `/^ya*y/,/[0-9]$/d` deletes from the first line that begins with yay, yaay, yaaay, etc. through the first line that ends with a digit

Multiple Commands

- Braces **{ }** can be used to apply multiple commands to an address

```
[/pattern/[,/pattern/]]{
command1
command2
command3
}
```

- Strange syntax:
  - The *opening brace* must be the last character on a line
  - The *closing brace* must be on a line by itself
  - Make sure there are no spaces following the braces

Sed Commands

- Although sed contains many editing commands, we are only going to cover the following subset:

  - **`s`** - substitute
  - **`a`** - append
  - **`i`** - insert
  - **`c`** - change
  - **`d`** - delete
  - **`p`** - print
  - **`y`** - transform
  - **`q`** - quit

sed Syntax

- Syntax: *sed [-n] [-e] [‘command’] [file…]*
  sed [-n] [-f scriptfile] [file…]
  - ***-n*** - only print lines specified with the print command (or the ‘p’ flag of the substitute (‘s’) command)
  - ***-f*** *scriptfile* - next argument is a filename containing editing commands
  - ***-e*** *command* - the next argument is an editing command rather than a filename, useful if multiple commands are specified
  - If the first line of a scriptfile is “***#n***”, sed acts as though ***-n*** had been specified

Print

- The Print command (**`p`**) can be used to force the pattern space to be output, useful if the ***-n*** option has been specified
- Syntax: **`[address1[,address2]]p`**
- Note: if the ***-n*** or ***#n*** option has not been specified, **`p`** will cause the line to be output twice!
- Examples:

  `1,5p` will display lines 1 through 5

  `/^$/,$p` will display the lines from the first blank line through the last line of the file

Substitute

- Syntax:
  [address(es)]s/pattern/replacement/[flags]
  - *pattern* - search pattern
  - *replacement* - replacement string for pattern
  - *flags* - optionally any of the following
    - **n** a number from 1 to 512 indicating which occurrence of *pattern* should be replaced
    - **g** global, replace all occurrences of *pattern* in pattern space
    - **p** print contents of pattern space

Substitute Examples

- **`s/Puff Daddy/P. Diddy/`**
  - Substitute P. Diddy for the first occurrence of Puff Daddy in *pattern space*
- **`s/Tom/Dick/2`**
  - Substitutes Dick for the second occurrence of Tom in the *pattern space*
- **`s/wood/plastic/p`**
  - Substitutes plastic for the first occurrence of wood and outputs (prints) *pattern space*

Replacement Patterns

- Substitute can use several special characters in the *replacement* string
  - **&** - replaced by the entire string matched in the regular expression for pattern
  - *****n* - replaced by the *n*th substring (or subexpression) previously specified using "\\(" and "\\)"
  - **** - used to escape the ampersand (&) and the backslash (\\)

Replacement Pattern Examples

```
"the UNIX operating system …"
s/.NI./wonderful &/
"the wonderful UNIX operating system …"
```

```
cat test1
first:second
one:two
sed 's/\(.*\):\(.*\)/\2:\1/' test1
second:first
two:one
```

```
sed 's/\([[:alpha:]]\)\([^ \n]*\)/\2\1ay/g'
```

- Pig Latin ("unix is fun" -> "nixuay siay unfay")

Append, Insert, and Change

- Syntax for these commands is a little strange because they **must** be specified on multiple lines
- **append** *[address]a*
  text
- **insert** *[address]i*
  text
- **change** *[address(es)]c*
  text
- append/insert for single lines only, not range

Append and Insert

- Append places *text* after the current line in pattern space
- Insert places *text* before the current line in pattern space
  - Each of these commands requires a **** following it.
    text must begin on the next line.
  - If text begins with whitespace, sed will discard it unless you start the line with a ****
- Example:

```
/<Insert Text Here>/i\
Line 1 of inserted text\
\         Line 2 of inserted text
```

would leave the following in the pattern space

```
Line 1 of inserted text
          Line 2 of inserted text
<Insert Text Here>
```

Change

- Unlike Insert and Append, Change can be applied to either a single line address or a range of addresses
- When applied to a range, the entire range is replaced by text specified with change, not each line
  - *Exception*: If the Change command is executed with other commands enclosed in **{ }** that act on a range of lines, **each line** will be replaced with *text*
- No subsequent editing allowed

Change Examples

- Remove mail headers, ie; the address specifies a range of lines beginning with a line that begins with From until the first blank line.
  - The first example replaces all lines with a single occurrence of <Mail Header Removed>.
  - The second example replaces each line with <Mail Header Removed>

```
/^From /,/^$/c\
  <Mail Headers Removed>
```

```
/^From /,/^$/{
   s/^From //p
   c\
   <Mail Header Removed>
   }
```

Using `!`

- If an address is followed by an exclamation point (**`!`**), the associated command is applied to all lines that don't match the address or address range
- Examples:

  `1,5!d` would delete all lines except 1 through 5

  `/black/!s/cow/horse/` would substitute "horse" for "cow" on all lines except those that contained "black"

"The brown cow" -> "The brown horse"

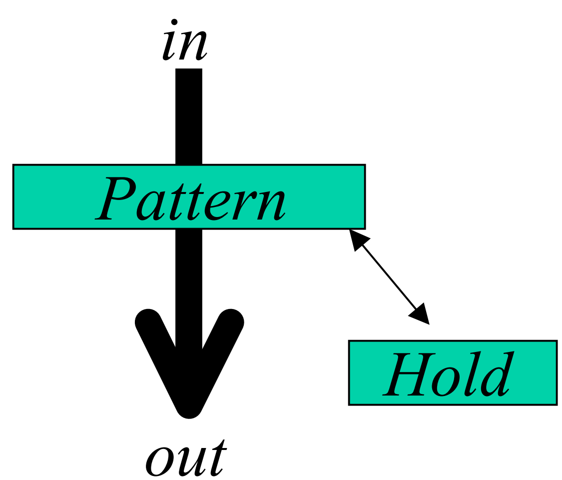
"The black cow" -> "The black cow"

Transform

- The Transform command (**y**) operates like **tr**, it does a one-to-one or character-to-character replacement
- Transform accepts zero, one or two addresses
- **`[address[,address]]y/abc/xyz/`**
  - every *a* within the specified address(es) is transformed to an *x*. The same is true for *b* to *y* and *c* to *z*
  - **`y/abcdefghijklmnopqrstuvwxyz/ABCDEFGHIJKLMNOPQRSTUVWXYZ/`** changes **all** lower case characters on the addressed line to upper case
  - If you only want to transform specific characters (or a word) in the line, it is much more difficult and requires use of the *hold space*

Pattern and Hold spaces

- **Pattern space**: Workspace or temporary buffer where a single line of input is held while the editing commands are applied
- **Hold space**: Secondary temporary buffer for temporary storage only




```
h, H, g, G, x
```

Quit

- Quit causes **sed** to stop reading new input lines and stop sending them to standard output
- It takes at most a single line address
  - Once a line matching the address is reached, the script will be terminated
  - This can be used to save time when you only want to process some portion of the beginning of a file
- Example: to print the first 100 lines of a file (like *head*) use:
  - **`sed '100q' filename`**
  - sed will, by default, send the first 100 lines of *filename* to standard output and then quit processing

Sed Advantages

- Regular expressions
- Fast
- Concise

Sed Drawbacks

- Hard to remember text from one line to another
- Not possible to go backward in the file
- No way to do forward references like `/..../+1`
- No facilities to manipulate numbers
- Cumbersome syntax

Awk

Programmable Filters

Why is it called AWK?

Aho

Weinberger

Kernighan

Awk Introduction

- **awk**'s purpose: A general purpose programmable filter that handles text (strings) as easily as numbers
  - This makes **awk** one of the most powerful of the Unix utilities
- **awk** processes *fields* while **sed** only processes lines
- **nawk** (new **awk**) is the new standard for **awk**
  - Designed to facilitate large **awk** programs
  - **gawk** is a free **nawk** clone from GNU
- **awk** gets it’s input from
  - files
  - redirection and pipes
  - directly from standard input

AWK Highlights

- A programming language for handling common data manipulation tasks with only a few lines of code
- **awk** is a *pattern-action* language, like **sed**
- The language looks a little like *C* but automatically handles input, field splitting, initialization, and memory management
  - Built-in string and number data types
  - No variable type declarations
- **awk** is a great prototyping language
  - Start with a few lines and keep adding until it does what you want

Awk Features over Sed

- Convenient numeric processing
- Variables and control flow in the actions
- Convenient way of accessing fields within lines
- Flexible printing
- Built-in arithmetic and string functions
- C-like syntax

Structure of an AWK Program

- An **awk** program consists of:
  - An optional BEGIN segment
    - For processing to execute prior to reading input
  - pattern - action pairs
    - Processing for input data
    - For each pattern matched, the corresponding action is taken
  - An optional END segment
    - Processing after end of input data

```
BEGIN {action}
pattern {action}
pattern {action}
  .
  .
  .
pattern { action}
END {action}
```

Running an AWK Program

- There are several ways to run an Awk program
  - ***awk 'program' input_file(s)***
    - program and input files are provided as command-line arguments
  - ***awk 'program'***
    - program is a command-line argument; input is taken from standard input (yes, awk is a filter!)
  - ***awk -f program_file input_files***
    - program is read from a file

Patterns and Actions

- Search a set of files for *patterns*.
- Perform specified *actions* upon lines or fields that contain instances of patterns.
- Does not alter input files.
- Process one input line at a time
- This is similar to **sed**

Pattern-Action Structure

- Every program statement has to have a *pattern* **or** an *action* **or** both
- Default *pattern* is to match all lines
- Default *action* is to print current record
- Patterns are simply listed; actions are enclosed in `{ }`
- **awk** scans a sequence of input *lines*, or *records*, one by one, searching for lines that match the pattern
  - Meaning of match depends on the pattern

Patterns

- Selector that determines whether *action* is to be executed
- *pattern* can be:
  - the special token **BEGIN** or **END**
  - regular expression (enclosed with //)
  - relational or string match expression
  - **`!`** negates the match
  - arbitrary combination of the above using **`&& ||`**
    - **`/NYU/`** matches if the string "NYU" is in the record
    - **`x > 0`** matches if the condition is true
    - **`/NYU/ && (name == "UNIX Tools")`**

BEGIN and END patterns

- **BEGIN** and **END** provide a way to gain control before and after processing, for initialization and wrap-up.
  - **BEGIN**: actions are performed before the first input line is read.
  - **END**: actions are done after the last input line has been processed.

Actions

- *action* may include a list of one or more C like statements, as well as arithmetic and string expressions and assignments and multiple output streams.
- *action* is performed on every line that matches *pattern*.
  - If *pattern* is not provided, *action* is performed on every input line
  - If *action* is not provided, all matching lines are sent to standard output.
- Since *patterns* and *actions* are optional, *actions* must be enclosed in braces to distinguish them from *pattern*.

An Example

```
ls | awk '
  BEGIN { print "List of html files:" }
  /\.html$/ { print }
  END { print "There you go!" }
  '
```

```
List of html files:
index.html
as1.html
as2.html
There you go!
```

Variables

- **awk** scripts can define and use variables

```
BEGIN { sum = 0 }
{ sum ++ }
END { print sum }
```

- Some variables are predefined

Records

- Default record separator is **newline**
  - By default, **awk** processes its input a line at a time.
- Could be any other *regular expression*.
- **RS**: record separator
  - Can be changed in **BEGIN** action
- **NR** is the variable whose value is the number of the current record.

Fields

- Each input line is split into fields.
  - **FS**: field separator: default is whitespace (1 or more spaces or tabs)
  - **`awk -F`***c* option sets **FS** to the character *c*
    - Can also be changed in BEGIN
  - **$0** is the entire line
  - **$1** is the first field, **$2** is the second field, ….
- Only fields begin with **$**, variables are unadorned

Simple Output From AWK

- Printing Every Line
  - If an action has no pattern, the action is performed to all input lines
    - **`{ print }`** will print all input lines to standard out
    - **`{ print $0 }`** will do the same thing
- Printing Certain Fields
  - Multiple items can be printed on the same output line with a single print statement
  - **`{ print $1, $3 }`**
  - Expressions separated by a comma are, by default, separated by a single space when printed (**`OFS`**)

Output (continued)

- **NF**, the Number of Fields
  - Any valid expression can be used after a **`$`** to indicate the contents of a particular field
  - One built-in expression is **NF**, or Number of Fields
  - **`{ print NF, $1, $NF }`** will print the number of fields, the first field, and the last field in the current record
  - **`{ print $(NF-2) }`** prints the third to last field
- Computing and Printing
  - You can also do computations on the field values and include the results in your output
  - **`{ print $1, $2 * $3 }`**

Output (continued)

- Printing Line Numbers
  - The built-in variable NR can be used to print line numbers
  - `{ print NR, $0 }` will print each line prefixed with its line number
- Putting Text in the Output
  - You can also add other text to the output besides what is in the current record
  - `{ print "total pay for", $1, "is", $2 * $3 }`
  - Note that the inserted text needs to be surrounded by double quotes

Fancier Output

- Lining Up Fields
  - Like C, Awk has a *printf* function for producing formatted output
  - *printf* has the form
    - *printf(format, val1, val2, val3, …)*

```
{ printf(“total pay for %s is $%.2f\n”,
          $1, $2 * $3) }
```

  - When using *printf*, formatting is under your control so no automatic spaces or newlines are provided by **awk**. You have to insert them yourself.

```
{ printf(“%-8s %6.2f\n”, $1, $2 * $3 ) }
```

Selection

- Awk patterns are good for selecting specific lines from the input for further processing
  - Selection by Comparison
    - `$2 >= 5 { print }`
  - Selection by Computation
    - ```
      $2 * $3 > 50 { printf("%6.2f for %s\n",
                                  $2 * $3, $1) }
      ```
  - Selection by Text Content
    - `$1 == "NYU"`
    - `$2 ~ /NYU/`
  - Combinations of Patterns
    - `$2 >= 4 || $3 >= 20`
  - Selection by Line Number
    - `NR >= 10 && NR <= 20`
      ```

Arithmetic and variables

- **awk** variables take on numeric (floating point) or string values according to context.
- User-defined variables are *unadorned* (they need not be declared).
- By default, user-defined variables are initialized to the null string which has numerical value 0.

Computing with AWK

- Counting is easy to do with Awk

```
$3 > 15 { emp = emp + 1}
END { print emp, "employees worked
      more than 15 hrs"}
```

- Computing Sums and Averages is also simple

```
{ pay = pay + $2 * $3 }
END { print NR, "employees"
      print "total pay is", pay
      print "average pay is", pay/NR
    }
```

Handling Text

- One major advantage of Awk is its ability to handle strings as easily as many languages handle numbers
- Awk variables can hold strings of characters as well as numbers, and Awk conveniently translates back and forth as needed
- This program finds the employee who is paid the most per hour:

```
# Fields: employee, payrate
$2 > maxrate { maxrate = $2; maxemp = $1 }
END { print "highest hourly rate:",
       maxrate, "for", maxemp }
```

String Manipulation

- String Concatenation
  - New strings can be created by combining old ones

```
    { names = names $1 " " }
END { print names }
```

- Printing the Last Input Line
  - Although NR retains its value after the last input line has been read, $0 does not

```
    { last = $0 }
END { print last }
```

Built-in Functions

- **awk** contains a number of built-in functions. length is one of them.
- Counting Lines, Words, and Characters using length (a poor man's **wc**)

```
    { nc = nc + length($0) + 1
      nw = nw + NF
    }
END { print NR, "lines,", nw, "words,", nc,
        "characters" }
```

- **substr(s, m, n)** produces the substring of *s* that begins at position *m* and is at most *n* characters long.

Control Flow Statements

- **awk** provides several control flow statements for making decisions and writing loops
- If-Then-Else

```
    $2 > 6 { n = n + 1; pay = pay + $2 * $3 }

END { if (n > 0)
          print n, "employees, total pay is",
               pay, "average pay is", pay/n
      else
          print "no employees are paid more
               than $6/hour"
    }
```

Loop Control

- While

```
# interest1 - compute compound interest
#   input: amount, rate, years
#   output: compound value at end of each year
{  i = 1
  while (i <= $3) {
         printf("\t%.2f\n", $1 * (1 + $2) ^ i)
         i = i + 1
  }
}
```

Do-While Loops

- Do While

```
do {
    statement1
    }
while (expression)
```

For statements

- For

```
# interest2 - compute compound interest
#   input: amount, rate, years
#   output: compound value at end of each year

{ for (i = 1; i <= $3; i = i + 1)
   printf("\t%.2f\n", $1 * (1 + $2) ^ i)
}
```

Arrays

- Array elements are not declared
- Array subscripts can have ***any*** value:
  - Numbers
  - Strings! (***associative arrays***)
- Examples
  - `arr[3]="value"`
  - `grade[″Mohri"]=40.3`

Array Example

```
# reverse - print input in reverse order by line

{ line[NR] = $0 }    # remember each line

END {
        for (i=NR; (i > 0); i=i-1) {
            print line[i]
        }
    }
```

- **`for`** loop to read associative array
  - **`for (v in array) { … }`**
  - Assigns to v each subscript of array (unordered)
  - Element is **`array[v]`**

Useful One (or so)-liners

- `END { print NR }`
- `NR == 10`
- `{ print $NF }`
- ```
    { field = $NF }
  END { print field }
  ```
- `NF > 4`
- `$NF > 4`
- ```
    { nf = nf + NF }
  END { print nf }
  ```

More One-liners

- `/Mehryar/ { nlines = nlines + 1 }`
  `END   { print nlines }`
- `$1 > max { max = $1; maxline = $0 }`
  `END     { print max, maxline }`
- `NF > 0`
- `length($0) > 80`
- `{ print NF, $0}`
- `{ print $2, $1 }`
- `{ temp = $1; $1 = $2; $2 = temp; print }`
- `{ $2 = ""; print }`

Even More One-liners

- ```
  { for (i = NF; i > 0; i = i - 1)
          printf("%s ", $i)
    printf("\n")
  }
  ```
- ```
  { sum = 0
    for (i = 1; i <= NF; i = i + 1)
          sum = sum + $i
    print sum
   }
  ```
- ```
  { for (i = 1; i <= NF; i = i + 1)
          sum = sum $i }
    END { print sum }
  }
  ```
  ```

Awk Variables

- $0, $1, $2, $NF
- NR - Number of records processed
- NF - Number of fields in current record
- FILENAME - name of current input file
- FS - Field separator, space or TAB by default
- OFS - Output field separator, space by default
- ARGC/ARGV - Argument Count, Argument Value array
  - Used to get arguments from the command line

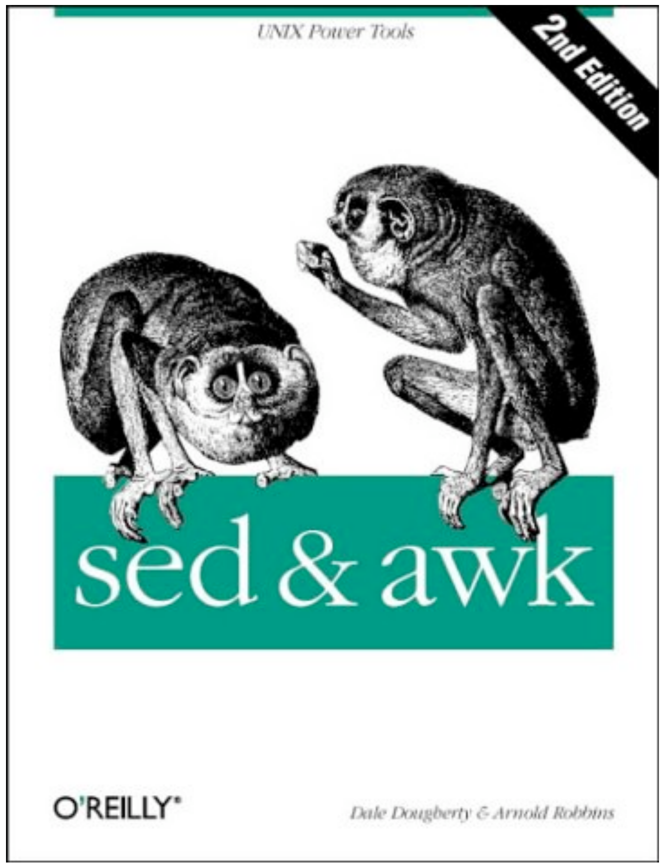
Operators

- = assignment operator; sets a variable equal to a value or string
- == equality operator; returns TRUE is both sides are equal
- != inverse equality operator
- && logical AND
- || logical OR
- ! logical NOT
- <, >, <=, >= relational operators
- +, -, /, *, %, ^
- String concatenation

Built-In Functions

- Arithmetic
  - **sin**, **cos**, **atan**, **exp**, **int**, **log**, **rand**, **sqrt**
- String
  - **length**, **substr, split**
- Output
  - **print**, **printf**
- Special
  - **system** - executes a Unix command
    - system(“clear”) to clear the screen
    - Note double quotes around the Unix command
  - **exit -** stop reading input and go immediately to the END pattern-action pair if it exists, otherwise exit the script

More Information



on the website