STATS 701
Data Analysis using Python

Lecture 18: the UNIX/Linux Command Line

UNIX/Linux: a (very) brief history

1960s: Multics (Bell Labs, MIT, GE), a time-sharing operating system

1970s: UNIX developed at Bell Labs

1980s: the UNIX wars https://en.wikipedia.org/wiki/Unix_wars

1990s: GNU/Linux emerges

2000s: MacOS developed based on UNIX

Bell labs film about UNIX from 1982: http://techchannel.att.com/play-video.cfm/2012/2/22/AT&T-Archives-The-UNIX-System

The Unix philosophy: do one thing well

1. Write programs that do one thing and do it well.
2. Write programs to work together.
3. Write programs to handle text streams, because that is a universal interface.

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These three design principles, articulated in the concise form above long after Unix was written, go a long way toward explaining how to approach the command line. For nearly any task you wish to accomplish, there almost certainly exists a way to do it (reasonably) easily by stringing together several different programs. **More information:** https://en.wikipedia.org/wiki/Unix_philosophy

Basic concepts

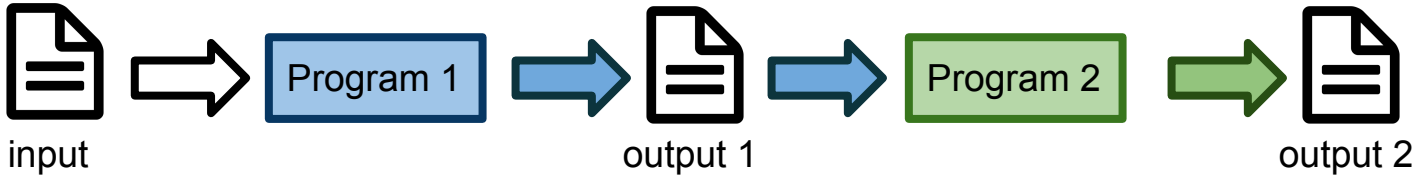
Shell : the program through which you interact with the computer.

provides the command line and facilitates typing commands and reading outputs.

Popular shells: bash (Bourne Again Shell), csh (C Shell), ksh (Korn Shell)

Redirect : take the output of one program and make it the input of another.

we'll see some simple examples in a few slides

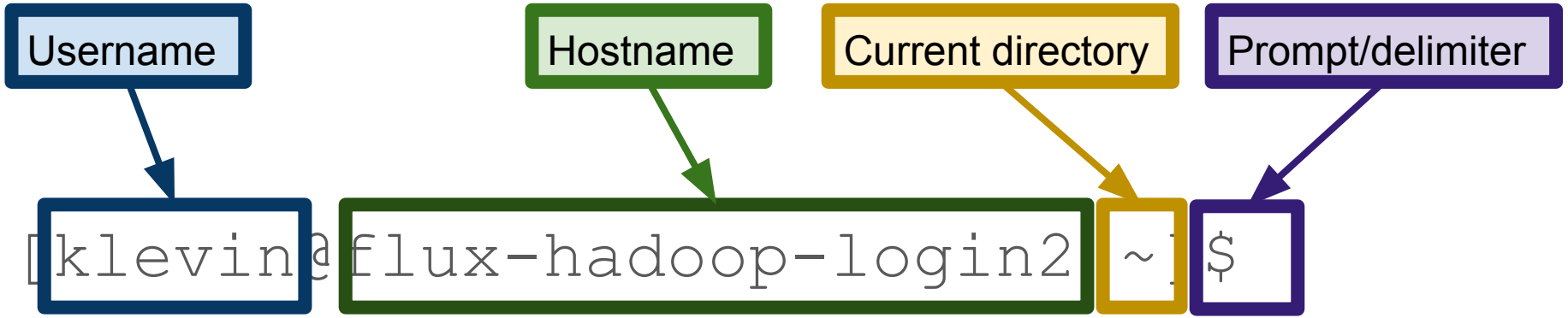


stdin, stdout, stderr : three special "file handles"

for reading inputs from the shell (stdin)

and writing output to the shell (stderr for error messages, stdout other information).

Parts of the command line prompt



Note: details of this will vary from one computer to the next (and it can be customized by the user), but this is the default on the Fladoop cluster. For information on customizing the command line prompt, see https://linuxconfig.org/bash-prompt-basics

Connecting to other machines: `ssh`

`ssh` (**S**ecure **Sh**ell) network protocol allows secure communication machines

Allows remote access to resources on, e.g., a server or compute cluster

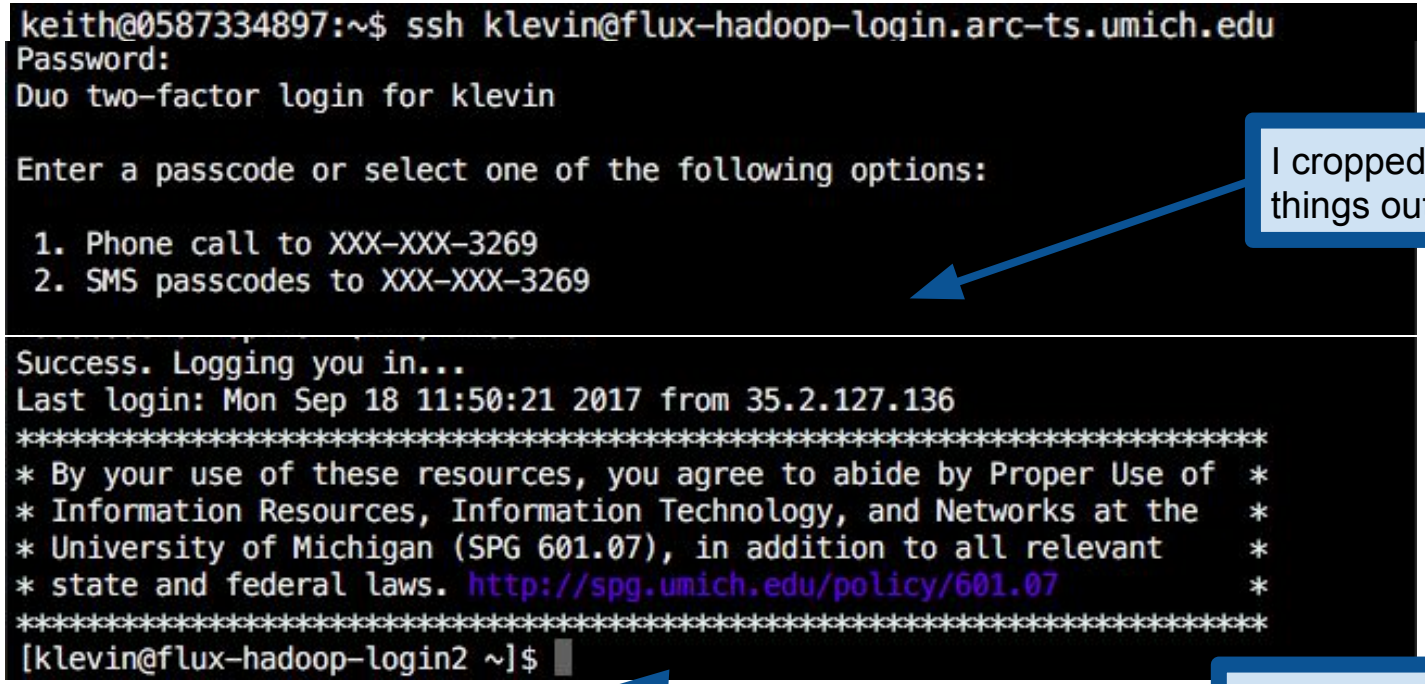
UNIX/Linux/MacOS: open a terminal, type “ssh user@machine”, and you’re off!

Windows: ssh does not come standard.

PuTTY: https://en.wikipedia.org/wiki/PuTTY

Cygwin: https://en.wikipedia.org/wiki/Cygwin

Typical `ssh` session



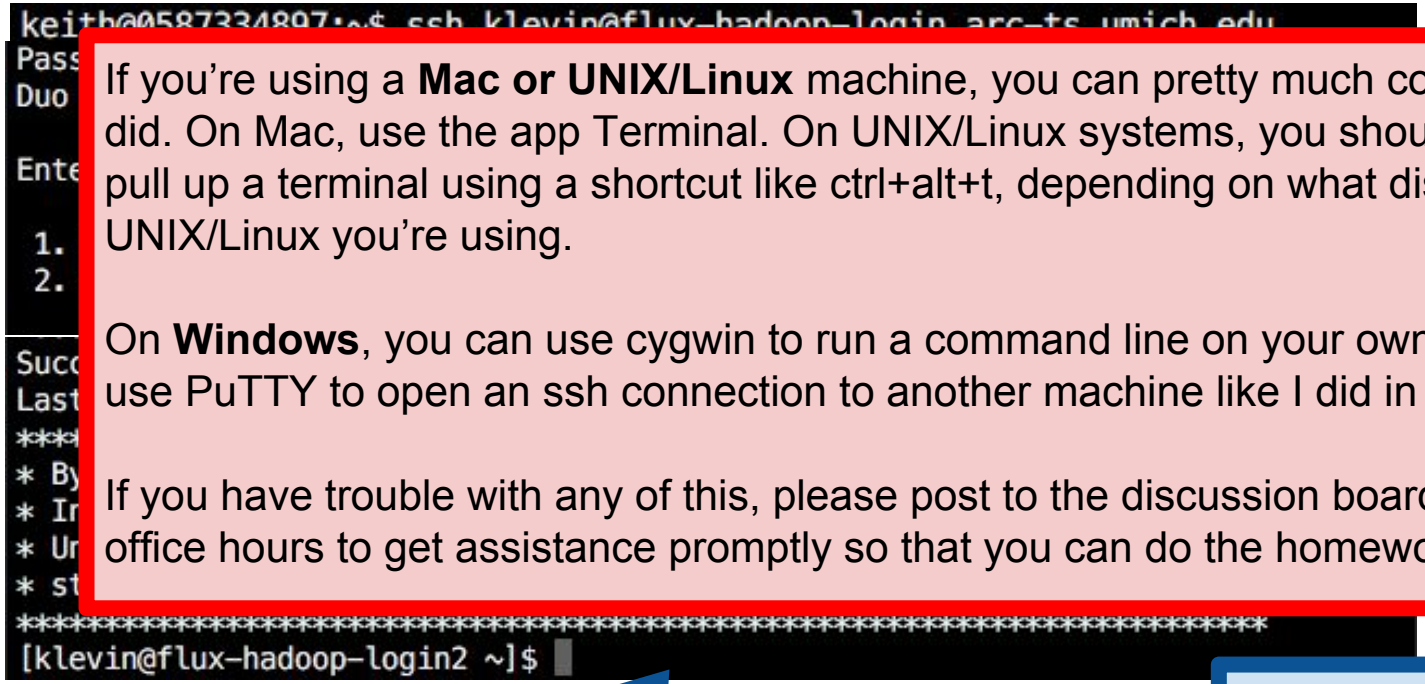
Secure shell (`ssh`) login to Fladoop, from the command line on my Mac (term)

I cropped a few security-related things out of here.

And now I have a command line prompt on the Fladoop cluster!

Typical `ssh` session

Secure shell (`ssh`) login to Fladoop, from the command line on my Mac (term)



If you're using a **Mac or UNIX/Linux** machine, you can pretty much copy what I just did. On Mac, use the app Terminal. On UNIX/Linux systems, you should be able to pull up a terminal using a shortcut like ctrl+alt+t, depending on what distribution of UNIX/Linux you're using.

On **Windows**, you can use cygwin to run a command line on your own machine, or use PuTTY to open an ssh connection to another machine like I did in this slide.

If you have trouble with any of this, please post to the discussion board and come to office hours to get assistance promptly so that you can do the homework.

And now I have a command line prompt on the Fladoop cluster!

Basic commands for navigating

`pwd` : "print/present working directory". Print the directory that you are currently in.

`ls` : list the contents of the current directory.

Try this. Type `pwd` or `ls` in your shell (either in terminal/cygwin or on Fladoop).

`cd dirname` : change the working directory to `dirname`.

Some special directory symbols:

- `~` : your home directory. `cd ~` will take you back to your home.
- `.` : the current directory. `cd .` will take you to where you are right now.
- `..` : the directory above the current directory.
  - If you're in `/home/klevin/stats`, then `cd ..` will take you to `/home/klevin`.

Example: `pwd`, `ls` and `cd`

```
keith@Steinhaus:~$ ssh -X klevin@flux-hadoop-login.arc-ts.umich.edu
Password:

    [...]

[klevin@flux-hadoop-login2 ~]$ pwd
/home/klevin
[klevin@flux-hadoop-login2 ~]$ ls
Myfile.txt  stats700f17
[klevin@flux-hadoop-login2 ~]$ cd stats700f17/
[klevin@flux-hadoop-login2 stats700f17]$ pwd
/home/klevin/stats700f17
[klevin@flux-hadoop-login2 stats700f17]$ ls .
hw1.tex  hw2.tex  hw3.tex
[klevin@flux-hadoop-login2 stats700f17]$ ls ..
myfile.txt  stats700f17
[klevin@flux-hadoop-login2 stats700f17]$ ls ~
myfile.txt  stats700f17
```

Getting help: man pages

When in doubt, the shell has built-in documentation, and it tends to be good!

`man cmdname` : brings up documentation about the command `cmdname`

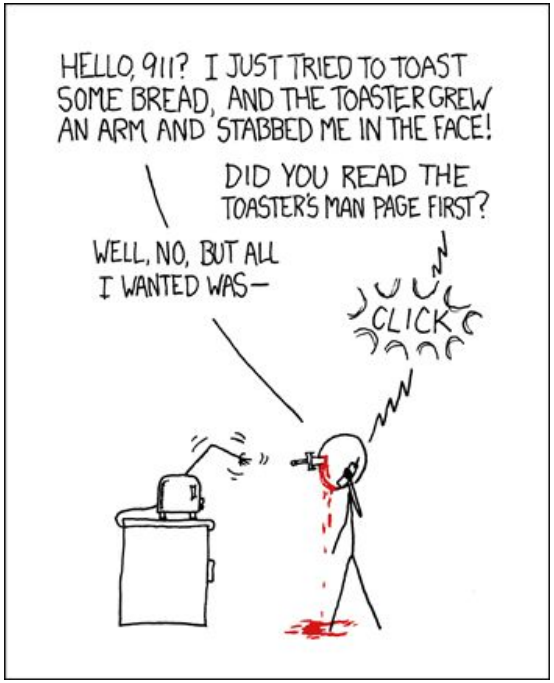
This help page is called a man (short for manual) page. These have a reputation for being terse, but once you get used to reading them, they are extremely useful!

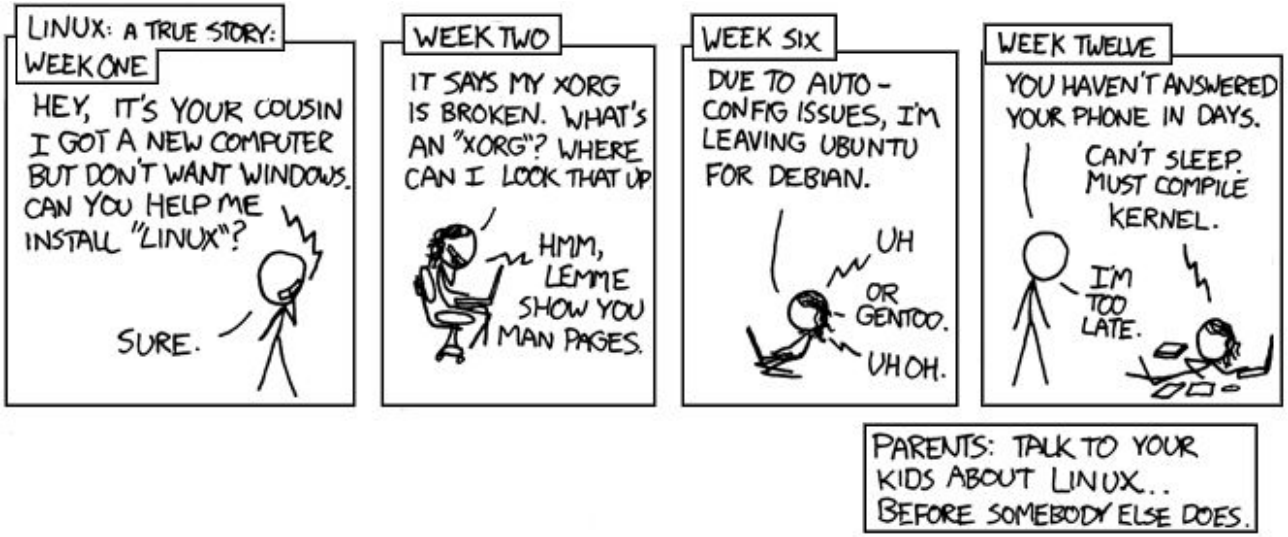
Some shells also have a command `apropos`:

`apropos topic` : lists all commands that might be relevant to `topic`.

Let's read some of the `ls` man page and see if we can make sense of it.

Relevant xkcds





Basic commands: actually doing things

In the next few slides, we'll look at some commands that actually let you do things like creating files and directories, reading files, and moving them around.

Follow along with the examples in your terminal, if you like (highly recommended).

Basic commands: `echo`

`echo string` : prints string to the shell.

```
keith@Steinhaus:~$ echo "hello world."
hello world.
keith@Steinhaus:~$ echo "hello world!"
-bash: !": event not found
keith@Steinhaus:~$ echo "hello world\!"
hello world\!
keith@Steinhaus:~$ echo 'hello world!'
hello world!
keith@Steinhaus:~$ echo "hello\tworld."
hello\tworld.
keith@Steinhaus:~$ echo -e "hello\tworld."
hello    world.
```

The shell tries to interpret the exclamation point as referencing a previous command rather than as text. Escaping doesn't do the trick here. Instead, use single-quotes to tell the shell not to try and process the string.

To print special characters (tabs, newlines, etc), use the flag `-e`, without which `echo` just prints what it's given.

Aside: redirections using >

What if I want to send output someplace other than the shell?

```
keith@Steinhaus:~$ echo -e  "hello\tworld." > myfile.txt
keith@Steinhaus:~$
```

Note: the other redirect, <, has a somewhat similar function, but is beyond our purposes here (stay tuned for command-line workshop at end of semester, perhaps?)

Redirect tells the shell to send the output of the program on the "greater than" side to the file on the "lesser than" side. **This creates the file on the RHS, an overwrites the old file, if it already exists!**

Basic commands: `cat`

`cat filename` : prints the contents of the file filename.

```
keith@Steinhaus:~$ cat myfile.txt
hello    world
keith@Steinhaus:~$
```

So `cat` is like `echo` but it takes a filename as argument instead of a string.

Basic commands: `head`

`head filename` : prints the first 10 lines of filename.

`head -n X filename` : prints the first X lines of filename.

```
keith@Steinhaus:~$ head ~/Teaching/Homeworks/HW1/homework1.tex
\documentclass[11pt]{article}

\usepackage{enumerate}
\usepackage{amsmath}
\usepackage{amsfonts}
\usepackage{hyperref}

\oddsidemargin 0mm
\evensidemargin 5mm
\topmargin -20mm
keith@Steinhaus:~$
```

Basic commands: `more`/`less`

`more` and `less` are two (very similar) programs for reading ASCII files.

```
[klevin@flux-hadoop-login2 stats700f17]$ less hw1.tex
[less takes up the whole screen]

This is just a dummy file that I wrote
as an example.
An actual tex file wouldn't look like this.
It would have a bunch of stuff like
\begin{definition}
An integer $p > 1$ is called \emph{prime}
is its only divisors are $1$ and $p$.
\end{definition}
and it would have a preamble
section declaring its document type
and a bunch of other stuff.
hw1.tex (END)
```

Note: press “q” to **q**uit `less`/`more` and return to the command line.

Basic commands: `mkdir`

`mkdir dirname` : creates a new directory called dirname, if it doesn't exist

```
[klevin@flux-hadoop-login2 stats700f17]$ ls
hw1.tex  hw2.tex  hw3.tex
[klevin@flux-hadoop-login2 stats700f17]$ mkdir hadoop_stuff
[klevin@flux-hadoop-login2 stats700f17]$ ls
hadoop_stuff  hw1.tex  hw2.tex    hw3.tex
[klevin@flux-hadoop-login2 stats700f17]$
```

Basic commands: `mv`

`mv file1 file2` : "moves" `file1` to `file2`, overwriting `file2`.

If `file2` is a directory, this places `file1` inside that directory, again replacing any existing file with the same **basename** as `file1`. /path/to/file/basename.txt

```
[klevin@flux-hadoop-login2 stats700f17]$ ls
hadoop_stuff  hw1.tex  hw2.tex    hw3.tex
[klevin@flux-hadoop-login2 stats700f17]$ mv hw2.tex homework2.tex
[klevin@flux-hadoop-login2 stats700f17]$ ls
hadoop_stuff  homework2.tex  hw1.tex  hw3.tex
[klevin@flux-hadoop-login2 stats700f17]$
[klevin@flux-hadoop-login2 stats700f17]$ mv hw1.tex hadoop_stuff
[klevin@flux-hadoop-login2 stats700f17]$ ls
hadoop_stuff  homework2.tex  hw3.tex
[klevin@flux-hadoop-login2 stats700f17]$ ls hadoop_stuff
Hw1.tex
[klevin@flux-hadoop-login2 stats700f17]$
```

Basic commands: `cp`

`cp file1 file2` : similar to `mv`, but creates a copy of `file1` with name `file2`

So `cp` is like `mv` but `file1` is copied instead of being renamed

```
[klevin@flux-hadoop-login2 stats700f17]$ cat homework2.tex
This is the second homework!
[klevin@flux-hadoop-login2 stats700f17]$ cp homework2.tex HW2.tex
[klevin@flux-hadoop-login2 stats700f17]$ cat homework2.tex
This is the second homework!
[klevin@flux-hadoop-login2 stats700f17]$ cat HW2.tex
This is the second homework!
[klevin@flux-hadoop-login2 stats700f17]$ ls
hadoop_stuff  homework2.tex  HW2.tex  hw3.tex
```

Note: to copy a directory, you must include the -r flag to cp: `cp -r dirname otherdirname`

Basic commands: `rm`

`rm filename` : deletes the file `filename`. **Be very very careful with this!**

```
[klevin@flux-hadoop-login2 stats700f17]$ ls
hadoop_stuff  homework2.tex  HW2.tex  hw3.tex
[klevin@flux-hadoop-login2 stats700f17]$ rm HW2.tex
[klevin@flux-hadoop-login2 stats700f17]$ ls
hadoop_stuff  homework2.tex  hw3.tex
[klevin@flux-hadoop-login2 stats700f17]$
```

Basic commands: `logout`

`logout`: close connection to the current machine

```
[klevin@flux-hadoop-login2 stats700f17]$ logout
Connection to flux-hadoop-login.arc-ts.umich.edu closed.
keith@Steinhaus:~$
```

Note: depending on the type of shell session in use, you may need to use `exit` or `ctrl-D` to log off.

Moving files between machines: scp (Secure copy)

`scp localfile username@hostname:path/to/file`

Copy a file from your machine to some other machine via ssh

`scp username@hostname:path/to/file localfile`

Copy a file from another machine to your machine via ssh

```
keith@Steinhaus:~$ scp myfile.txt
klevin@flux-hadoop-login.arc-ts.umich.edu:~/stats700f17/myfile.txt
Password:
[authentication]
myfile.txt                                    100%   14     0.0KB/s   00:00
keith@Steinhaus:~$ ssh -X klevin@flux-hadoop-login.arc-ts.umich.edu
Password:
[authentication]
[klevin@flux-hadoop-login1 ~]$ ls stats700f17/
hadoop_stuff  homework2.tex  hw3.tex  myfile.txt
```

You will need `scp` for homeworks

If you are on UNIX/Linux/Mac, you can just use scp from the command line

If you are on Windows, make sure you have either:

1. `cygwin` installed and working
2. PuTTY installed with `pscp` working

You should try and copy a file to/from Fladoop to make sure everything works

And come talk to me if there are problems!

We've only scratched the surface!

The UNIX command line is extremely powerful!

Offers numerous tools for working with text and general data wrangling:

`grep`, `sed`, `awk`, `tr`, `cut`, ...

Ability to use the command line is crucial to being a good "data scientist"

- Command line, once you're good at it, makes things VERY fast!
- 2-3 lines of shell script to do what would take an entire Python program!

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Command line, once you're good at it, makes things VERY fast!

2-3 lines of shell script to do what would take an entire Python program!

If time allows, we'll come back to some of these tools at the end of the course.

Readings

Required:

Introduction to Unix commands: https://kb.iu.edu/d/afsk

Includes all the commands we discussed today, and a few more that you don't need to know well, but are worth being aware of.

Recommended:

Survival guide for Unix newbies: http://matt.might.net/articles/basic-unix/

More thorough discussion, including advanced commands like grep

"GNU/Linux Command−Line Tools Summary" by Gareth Anderson

Comprehensive introduction to the command line and the UNIX/Linux design philosophy in general.

http://tldp.org/LDP/GNU-Linux-Tools-Summary/GNU-Linux-Tools-Summary.pdf