A Course in Geophysical Image Processing with Seismic Unix:
GPGN 461/561 Lab
Fall 2015

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November 2, 2015
## Contents

1 Seismic Processing Lab- Preliminary issues .................................................. 12
   1.1 Motivation for the lab ................................................................. 12
   1.2 Unix and Unix-like operating systems .......................................... 13
      1.2.1 Steep learning curve .......................................................... 13
   1.3 Logging in ....................................................................................... 14
   1.4 What is a Shell? ............................................................................. 14
   1.5 The working environment .............................................................. 15
   1.6 Setting the working environment .................................................... 16
   1.7 Choice of editor ............................................................................ 16
   1.8 The Unix directory structure .......................................................... 18
   1.9 Scratch and Data directories ............................................................ 20
   1.10 Shell environment variables and path ............................................. 21
      1.10.1 The path or PATH ................................................................. 22
      1.10.2 The CWPROOT variable ........................................................ 22
   1.11 Shell configuration files ................................................................. 22
   1.12 Setting up the working environment ................................................. 22
      1.12.1 The CSH-family ................................................................. 23
      1.12.2 The SH-family ................................................................. 24
   1.13 Unix help mechanism- Unix man pages ........................................... 24

2 Lab Activity #1 - Getting started with Unix and SU ......................................... 26
   2.1 Pipe |, redirect in <, redirect out >, and run in background & .......... 28
   2.2 Stringing commands together ............................................................ 29
      2.2.1 Questions for discussion .......................................................... 30
   2.3 Unix Quick Reference Cards .............................................................. 30

3 Lab Activity #2 - viewing data ........................................................................... 33
   3.0.1 Data image examples ................................................................. 33
   3.1 Viewing an SU data file: Wiggle traces and Image plots .................... 34
      3.1.1 Wiggle traces ................................................................. 34
      3.1.2 Image plots ................................................................. 35
   3.2 Greyscale ....................................................................................... 35
   3.3 Legend ; making greyscale values scientifically meaningful ............... 38
   3.4 Display balancing and display gaining ............................................... 38
3.5  Homework problem #1 - Due dates Thursday 3 Sept 2015 and Tuesday 8
    September 2015 ................................................................. 45
3.6  Concluding Remarks .......................................................... 45
    3.6.1  What do the numbers mean? ........................................... 45

4  Help features in Seismic Unix .................................................. 47
    4.1  The selfdoc ................................................................. 47
    4.2  Finding the names of programs with: suiname ....................... 48
    4.3  Lab Activity #3 - Exploring the trace header structure .......... 50
        4.3.1  What are the trace header fields-sukeyworld? ............... 50
    4.4  Concluding Remarks ........................................................ 64

5  Lab Activity #4 - Migration/Imaging as depth conversion ............... 66
    5.1  Imaging as the solution to an inverse problem ....................... 66
    5.2  Inverse scattering imaging as time-to-depth conversion ........... 67
        5.2.1  Migration as a mapping of data from time to space .......... 67
        5.2.2  Migration as focusing followed by depth conversion ........ 68
    5.3  Time-to-depth with suttolz; depth-to-time with suztot ........... 68
    5.4  Time to depth conversion of a test pattern ........................ 71
        5.4.1  How time-depth and depth-time conversion works ............. 72
        5.4.2  How to calculate the depths Z1, Z2, and Z3 ................. 73
    5.5  Sonar and Radar, bad header values and incomplete information .... 73
    5.6  The sonar data .......................................................... 74
    5.7  Homework Problem - #2 - Time-to-depth conversion of the sonar.su
        and the radar.su data. Due Thursday 10 September 2015 and Tuesday 15
        September 2015, for the respective sections ........................ 76
    5.8  Concluding Remarks ........................................................ 76
        5.8.1  The sonar - seismic analogy ....................................... 76

6  Zero-offset (aka poststack) migration ......................................... 77
    6.1  Migration as reverse time propagation ................................ 78
    6.2  Lab Activity #5 - Hagedoor’s graphical migration .................. 82
    6.3  Migration as a Diffraction stack ....................................... 85
    6.4  Migration as a mathematical mapping .................................... 87
    6.5  Concluding Remarks ........................................................ 88

7  Lab Activity #6 - Several types of migration ................................ 89
    7.1  Different types of “velocity” .......................................... 89
        7.1.1  Velocity conversion \( v_{rms}(t) \) to \( v_{int}(t) \) ............ 89
    7.2  Stolt or \((f,k)\)-migration ............................................ 91
        7.2.1  Stolt migration of the Simple model data ...................... 91
    7.3  Gazdag or Phase-shift migration ....................................... 94
    7.4  Claerbout’s finite-difference migration ................................ 96
7.5 Ristow and Ruhl’s Fourier finite-difference migration .......... 96
7.6 Stoffa’s split-step migration ................................... 97
7.7 Gazdag’s Phase-shift Plus Interpolation migration ............... 98
7.8 Lab Activity #7 - Shell scripts .................................. 99
7.9 Homework #3 - Due 17 Sept 2015 (Thursday session) and 22 Sept 2015 (Tuesday Session). ................................. 101
7.9.1 Hints .......................................................... 101
7.10 Lab Activity #8 - Kirchhoff Migration of Zero-offset data ..... 102
7.11 Spatial aliasing ..................................................... 105
7.11.1 Interpreting the result ......................................... 105
7.11.2 Recognizing spatial aliasing of data in the space-time domain . 107
7.11.3 Recognizing spatial aliasing in the (f,k) domain .......... 107
7.11.4 Remedies for spatial aliasing ................................ 109
7.12 Concluding Remarks .............................................. 114

8 Zero-offset $v(t)$ and $v(x,z)$ migration of real data, Lab Activity #9 115
8.1 Stolt and Phaseshift $v(t)$ migrations ................................. 116
8.1.1 Questions for discussion ........................................ 118
8.1.2 Phase Shift migration .......................................... 119
8.1.3 Questions for discussion ........................................ 119
8.2 Lab Activity #10: FD, FFD, PSPI, Split step, Gaussian Beam $v(x,z)$ migrations ........................................... 119
8.3 Homework Assignment #4 Due 24 Sept 2015 Thursday session, 28 Sept 2015 Tuesday group - Migration comparisons ..................... 121
8.4 Concluding Remarks .............................................. 121

9 Data before stack ..................................................... 122
9.1 Lab Activity #11 - Reading and Viewing Seismic Data ............ 122
  9.1.1 Reading the data .............................................. 123
9.2 Getting to know our data - trace header values .................... 123
  9.2.1 Setting geometry .............................................. 124
9.3 Getting to know our data - Viewing the data ....................... 125
  9.3.1 Windowing Seismic Data ..................................... 125
9.4 Getting to know your data - Bad or missing shots, traces, or receivers ... 127
  9.4.1 Viewing a specific Shot gather ................................ 127
  9.4.2 Charting source and receiver positions ...................... 128
9.5 Geometrical spreading aka divergence correction .................. 129
  9.5.1 Some theory of seismic amplitudes ............................ 129
  9.5.2 Lab Activity #12 Gaining the data ......................... 130
  9.5.3 Statistical gaining ........................................... 131
  9.5.4 Model based divergence correction ........................... 133
9.6 Getting to know our data - Different Sorting Geometries .......... 133
  9.6.1 Lab Activity #13 Common-offset gathers ..................... 133
  9.6.2 Lab Activity #14 CMP (CDP) Gathers ....................... 134
9.6.3 Sort and gain ............................................. 134
9.6.4 Viewing the headers ................................... 136
9.6.5 Stacking Chart ......................................... 139
9.6.6 Capturing a Single CMP gather ......................... 139
9.7 Quality control through raw, CV, and brute stacks ....... 142
9.7.1 Lab Activity #15 - “Raw” Stacks, CV Stacks, and Brute Stacks 142
9.8 Homework: #5 Due Thursday 1 Oct 2015 and Tues 6 Oct 2015 prior to 9:00AM ............................................. 143
9.8.1 Are we done with gaining? .............................. 144
9.9 Concluding Remarks ...................................... 144

10 Velocity Analysis - Preview of Semblance and noise suppression 146
10.1 The Radon or ($\tau - p$) Transform ........................ 149
10.1.1 How filtering in the Radon domain differs from $f - k$ filtering .. 152
10.1.2 Semblance and Radon for a CDP gather ................ 152
10.2 Multiple suppression - Lab Activity #17 Radon transform .... 157
10.2.1 Homework assignment #6, Due Thursday 8 Oct 2015 (before 9:00am) and on Tues 13 Oct 2015 .......................... 160
10.2.2 We are not finished with multiple suppression and velocity analysis. 162
10.3 Muting revisited ......................................... 162
10.3.1 The stretch mute .................................... 162
10.3.2 Muting specific arrivals. .............................. 164
10.3.3 Lab Activity #16 – muting the data ..................... 165
10.3.4 Identifying waves to be muted ......................... 165
10.3.5 How to pick mute values. ............................ 165
10.3.6 The shape of the wavelet ............................ 166
10.3.7 Further processing ................................. 167
10.3.8 The at command: using the computer while you are asleep .. 168
10.4 Homework Assignment #7 due Thursday 15 Oct 2015 and Tuesday 27 October 2015, before 9:00 AM. .......................... 170
10.5 Concluding remarks ...................................... 172

11 Spectral methods and advanced gaining methods for seismic data 173
11.1 Common assumptions of spectral method processing ........ 173
11.1.1 Causality ........................................ 175
11.1.2 Minimum phase (aka minimum delay) .................... 175
11.1.3 White spectrum .................................... 175
11.1.4 Linear systems .................................... 176
11.2 The three mathematical languages of signal processing .... 177
11.2.1 The Forward and Inverse Fourier Transform ............ 177
11.3 Convolution, cross-correlation, and autocorrelation .......... 178
11.3.1 Convolution .................................... 178
11.3.2 Lab Activity #18: Frequency filtering .................. 178
11.3.3 Lab Activity #19: Spectral whitening of the fake data .......................... 180
11.3.4 The Forward and Inverse Z-transform ............................................. 183
11.3.5 The inverse Z-transform .............................................................. 183
11.4 Deconvolution ................................................................................. 184
11.4.1 Convolution of a wavelet with a reflectivity series ......................... 184
11.4.2 Convolution with a wavelet.......................................................... 185
11.4.3 Deconvolution .............................................................................. 186
11.4.4 Deconvolution of functions represented by their Z-transforms ......... 186
11.4.5 Division in the frequency domain - Deterministic deconvolution ..... 186
11.5 Cross- and auto-correlation ............................................................ 189
11.5.1 Z-transform view of cross-correlation ............................................. 189
11.5.2 Cross correlation and auto correlation in SU suxcor and suacor ........ 191
11.6 Lab activity #20: Wiener (least-squares) filtering .............................. 192
11.6.1 A matrix view of the convolution model ........................................ 192
11.6.2 Designing wavelet shaping filters – Wiener filtering ....................... 194
11.6.3 Least-squares (Wiener) filter design ............................................... 195
11.7 Spiking deconvolution ..................................................................... 196
11.7.1 Spiking Deconvolution in SU ......................................................... 196
11.7.2 Multiple suppression by Wiener filtering—Gapped prediction error filtering ......................................................................................... 199
11.7.3 Applying gapped decon in SU – supef .............................................. 201
11.8 What (else) did predictive decon do to our data? ............................... 203
11.8.1 Deconvolution in the Radon domain ............................................. 204
11.9 FX Decon ......................................................................................... 204
11.10 Lab Activity #20: Wavelet shaping .................................................. 204
11.11 Advanced gaining operations ........................................................... 206
11.11.1 Correcting for differing source strengths ...................................... 207
11.11.2 Correcting for differing receiver gains ......................................... 207
11.12 Filling in missing shots ................................................................... 208
11.13 Muting NMO corrected data ........................................................... 210
11.14 Ghost reflections ............................................................................ 210
11.15 Surface related multiple elimination ............................................... 211
11.15.1 The auto-convolution model of multiples ..................................... 211
11.16 Homework Assignment #8, Due Thursday 5 Nov, before 9:00am and Tuesday 3 Nov 2015 ................................................................. 211
11.16.1 How are we doing on multiple suppression and NMO Stack? .... 213
11.17 Concluding Remarks ..................................................................... 213

12 Velocity Analysis on more CDP gathers and Dip Move-Out ...................... 214
12.0.1 Applying migration ..................................................................... 218
12.0.2 Homework #9 - Velocity analysis for stack, Due Thurs 12 Nov 2015, before 9:00am and Tuesday 10 November 2015. (This assignment is paired with Homework #10 in the next chapter, so be aware of this.)

12.1 Other velocity files

12.1.1 Velocity analysis with constant velocity (CV) stacks

12.2 Dip Moveout (DMO)

12.2.1 Implementing DMO

12.3 Concluding Remarks

13 Velocity models and horizon picking

13.1 Horizon picking and smooth model building

13.2 Migration velocity tests

13.2.1 Homework #10 - Build a velocity model and perform Gaussian Beam Migration, Due 12 Nov 2015 for both sections.

13.3 Concluding remarks

14 Prestack Migration

14.1 Prestack Stolt migration

14.2 Prestack Depth Migration

14.3 Concluding remarks
List of Figures

1.1 A quick reference for the *vi* editor. .................................. 17

2.1 The *suplane* test pattern. .............................................. 27
2.2 a) The *suplane* test pattern. b) the Fourier transform (time to frequency) of the *suplane* test pattern via *suspecfx*. .................................. 29
2.3 UNIX Quick Reference card p1. From the University References .... 31
2.4 UNIX Quick Reference card p2. ........................................ 32

3.1 Image of *sonar.su* data (no perc). Only the largest amplitudes are visible. 36
3.2 Image of *sonar.su* data with perc=99. Clipping the top 1 percentile of amplitudes brings up the lower amplitude amplitudes of the plot. .... 37
3.3 Image of *sonar.su* data with perc=99 and legend=1. .................. 39
3.4 Comparison of the default, hsv0, hsv2, and hsv7 colormaps. Rendering these plots in grayscale emphasizes the location of the bright spot in the colorbar. .................................................. 40
3.5 Image of *sonar.su* data with perc=99 and legend=1. .................. 41
3.6 Image of *sonar.su* data with median balancing and perc=99 ....... 43
3.7 Comparison of *seismic.su* median-normalized, with the same data with no median balancing. Amplitudes are clipped to 3.0 in each case. Notice that there are features visible on the plot without median balancing that cannot be seen on the median normalized data. .................. 44

5.1 Cartoon showing the simple shifting of time to depth. The spatial coordinates $x$ do not change in the transformation, only the time scale $t$ is stretched to the depth scale $z$. Note that vertical relief looks greater in a depth section as compared with a time section. .................. 67
5.2 a) Test pattern. b) Test pattern corrected from time to depth. c) Test pattern corrected back from depth to time section. Note that the curvature seen depth section indicates a non piecewise-constant $v(t)$. Note that the reconstructed time section has waveforms that are distorted by repeated sinc interpolation. The sinc interpolation applied in the depth-to-time calculation has not had an anti-alias filter applied. .................. 69
5.3 a) Cartoon showing an idealized well log. b) Plot of a real well log. A real well log is not well represented by piecewise constant layers. c) The third plot is a linearly interpolated velocity profile following the example in the text. This approximation is a better first-order approximation of a real well log.

6.1 Geometry of Karcher’s prospect, note semicircular arcs indicating that Karcher understood the relation of surfaces of constant traveltime to what is seen on a seismogram.

6.2 a) Synthetic Zero offset data. b) Simple earth model.

6.3 The Hagedoorn method applied to the arrivals on a single seismic trace.

6.4 Hagedoorn’s method applied to the simple data of Fig 6.2. Here circles, each centered at time $t = 0$ on a specific trace, pass through the maximum amplitudes on each arrival on each trace. The circle represents the locus of possible reflection points in $(x, z)$ where the signal in time could have originated.

6.5 The dashed line is the interpreted reflector taken to be the envelope of the circles.

6.6 The light cone representation of the constant-velocity solution of the 2D wave equation. Every wavefront for both positive and negative time $t$ is found by passing a plane parallel to the $(x, z)$-plane through the cone at the desired time $t$. We may want to run time backwards for migration.

6.7 The light cone representation for negative times is now embedded in the $(x, z, t)$-cube. A seismic arrival to be migrated at the coordinates $(\xi, \tau)$ is placed at the apex of the cone. The circle that we draw on the seismogram for that point is the set of points obtained by the intersection of the cone with the $t = 0$-plane.

6.8 Hagedoorn’s method of graphical migration applied to the diffraction from a point scatterer. Only a few of the Hagedoorn circles are drawn, here, but the reader should be aware that any Hagedoorn circle through a diffraction event will intersect the apex of the diffraction hyperbola.

6.9 The light cone for a point scatterer at $(x, z)$. By classical geometry, a vertical slice through the cone in $(x, t)$ (the $z = 0$ plane where we record our data) is a hyperbola. Time migrations collapse diffraction hyperbolae to their respective apex points. Depth migrations map these apex points into the $(x, z)$ (2D) plane.

6.10 Cartoon showing the relationship between types of migration. a) shows a point in $(\xi, \tau)$, b) the impulse response of the migration operation in $(x, z)$, c) shows a diffraction, d) the diffraction stack as the output point $(x, z)$.
7.1 a) Spike data, b) the Stolt migration of these spikes. The curves in b) are impulse responses of the migration operator, which is what the curves in the Hagadoorn method were approximating. Not only do the curves represent every point in the medium where the impulses could have come from, the amplitudes represent the strength of the signal from that respective location.

7.2 a) The simple.su data b) The same data trace-interpolated, the interp.su data. You can recognize spatial aliasing in a), by noticing that the peak of the waveform on a given trace does not line up with the main lobe of the neighboring traces. The data in b) are the same data as in a), but with twice as many traces covering the same spatial range. Each peak aligns with part of the main lobe of the waveform on the neighboring trace, so there is no spatial aliasing.

7.3 a) Simple data in the \((f,k)\) domain, b) Interpolated simple data in the \((f,k)\) domain, c) Simple data represented in the \((k_z,k_x)\) domain, d) Interpolated simple data in the \((k_z,k_x)\) domain. The simple.su data are truncated in the frequency domain, with the aliased portions folded over to lower wavenumbers. The interpolated data are not folded.

7.4 a) simple.su data unfiltered, b) simple.su data filtered with a 5,10,20,25 Hz trapezoidal filter, c) Stolt migration of unfiltered data, d) Stolt migration of filtered data, e) interpolated data, f) Stolt migration of interpolated data. Clearly, the most satisfying result is obtained by migrating the interpolated data.

7.5 The results of a suit of Stolt migrations with different dip filters applied.

7.6 The \((k_1,k_2)\) domain plots of the simple.su data with the respective dip filters applied in the Stolt migrations of Figure 7.5.

9.1 The first 1000 traces in the data.

9.2 a) Shot 200 as wiggle traces b) as an image plot.

9.3 Gaining tests a) no gain applied, b) \texttt{tpow=1} c) \texttt{tpow=2}, d) \texttt{jon=1}. Note that in the text we often use \texttt{jon=1} because it is convenient, not because it is optimal. It is up to you to find better values of the gaining parameters. Once you have found those, you should continue using those.

9.4 Common Offset Sections a) \texttt{offset=-262 meters.} b) \texttt{offset=-1012 meters.} c) \texttt{offset=-3237 meters.} Gaining is done via \texttt{... sugain jon=1 ...}.

9.5 A stacking chart is merely a plot of the header CDP field versus the offset field. Note white stripes indicating missing shots.

9.6 CMP 265 of the gained data.

9.7 a) “Raw” stack: no NMO correction, b) CV Stack \texttt{vnmo=1500}, c) CV Stack \texttt{vnmo=2300} d) Brute Stack \texttt{vnmo=1500,1800,2300} \texttt{tnmo=0.0,1.0,3.0}
10.1 Semblance plot of CDP 265. The white dashed line indicates a possible location for the NMO velocity curve. Water-bottom multiples are seen on the left side of the plot. Multiples of strong reflectors shadow the brightest arrivals on the NMO velocity curve.

10.2 CMP 265 NMO corrected with \(vnmo=1500\). Arrivals that we want to keep curve up, whereas multiple energy is horizontal, or curves down.

10.3 a) Suplane data b) its Radon transform. Note that a linear Radon transform has isolated the three dipping lines as three points in the \((\tau-p)\) domain. Note that the fact that these lines terminate sharply causes 4 tails on each point in the Radon domain.

10.4 The \textit{suplane} test pattern data with the steepest dipping arrival surgically removed in the Radon domain.

10.5 a) Synthetic data similar to CDP=265. b) Synthetic data plus simulated water-bottom multiples. c) Synthetic data plus water-bottom multiples, plus select pegleg multiples.

10.6 a) Synthetic data similar to CDP=265. b) Synthetic data plus simulated water-bottom multiples. c) Synthetic data plus water-bottom multiples, plus select pegleg multiples.

10.7 a) Synthetic data in the Radon domain b) Synthetic data plus simulated water-bottom multiples in the Radon domain. c) Synthetic data plus water-bottom multiples, plus select pegleg multiples in the Radon domain.

10.8 CMP 265 NMO corrected with \(vnmo=1500\), displayed in the Radon transform \((\tau-p)\) domain. Compare this figure with Figure 10.2. The repetition indicates multiples.

10.9 CDP 265 NMO corrected with the velocity function \(vnmo=1500,1800,2300\) \(tnmo=0.0,1.0,2.0\) but with no stretch mute parameter applied. NMO stretch artefacts appear in the long offset, shallow portion of the section.

10.10 An average over all of the shots showing direct arrivals, head waves, wide angle reflections, and a curve along with muting may be applied to eliminate these waves.

11.1 Example of a far-field airgun source signature.

11.2 a) Amplitude spectra of the traces in CMP=265, b) Amplitude spectra after filtering.

11.3 a) Original fake data b) fake data with spectral whitening applied. Note that spectral whitening makes the random background noise bigger.

11.4 Deterministic decon of CDP 265 using the farfield airgun signature estimate from Fig 11.1.

11.5 a) Autocorrelation waveforms of the \textit{fake.su} data b) Autocorrelation waveforms of the same data after predictive (spiking) decon.
I started writing these notes in 2005 to aid in the teaching of a seismic processing lab that is part of the courses Seismic Processing GPGN452 (later redesignated GPGN461) and Advanced Seismic Methods (GPGN561) in the Department of Geophysics, Colorado School of Mines, Golden, CO.

In October of 2005, Geophysics Department chairman Terry Young asked me if I would be willing to help teach the Seismic Processing Lab. This was the year following Ken Larner’s retirement. Terry was teaching the lecture, but decided that the students should have a practical problem to work on. The choice was between data collected in the Geophysics Field Camp the previous summer, or the an industry dataset that was acquired near the Viking Graben in the North Sea. The latter dataset was brought by Terry from Carnegie Mellon University. We chose the latter, and decided that the students should produce as their final project a poster presentation similar to those seen at the SEG annual meeting. Terry seemed to think that we could just hand the students the SU User’s Manual and the data, and let them have at it. I felt that more needed to be done to instruct students in the subject of seismic processing while simultaneously introducing them to the topics of navigating the Unix operating system, performing some simple shell language programming, and of course, using Seismic Unix.

In the years that have elapsed my understanding of the subject of seismic processing has continued to grow. In each successive semester I have gathered more examples and figured out how to apply more types of processing techniques to the data.

My vision of the material is that we are replicating the seismic processors’ base experience, such as a professional might have obtained in the petroleum industry in the late 1970s. The idea is not to train students in a particular routine of processing, but to teach them how to think like geophysicists. Because seismic processing techniques are not exclusively used on petroleum industry data, the title of “Geophysical Image Processing” was chosen.
Chapter 1

Seismic Processing Lab- Preliminary issues

1.1 Motivation for the lab

In the lecture portion of the course GPGN452/561 (now GPGN461/561) (Advanced Seismic Methods/Seismic Processing) the student is given a word, picture, and chalkboard introduction of the process of seismic data acquisition and the application of a myriad of processing steps for converting raw seismic data into a scientifically useful picture of the earth’s subsurface.

This lab is designed to provide students with practical hands-on experience in the reality of applying seismic processing techniques to synthetic and real data. The course, however, is not a “training course in seismic processing,” as one might get in an industrial setting. Rather than training a student to use a particular collection of software tools, we believe that it is better that the student cultivate a broader understanding of the subject of seismic processing. We seek also to help students develop some practical skills that will serve them in a general way, even if they do not go into the field of oil and gas exploration and development.

Consequently, we make use of freely available open-source software (the Seismic Unix package) running on small-scale hardware (Linux-based PCs). Students are also encouraged to install the SU software on their own personal (Linux or Mac) PCs, so that they may work (and play) with the data and with the codes, at their leisure.

Given the limited scale of our available hardware and time, our goal is modest, to introduce students to seismic data processing through a 2D single-component processing application.

The intended range of experience is approximately that which a seismic processor of mid to late 1970s might have experienced on a vastly slower, more expensive, and more difficult to use processing platform.

Our technology is different from that of the 1970s geophysicist. This section is included to help familiarize the student with that technology.
1.2 Unix and Unix-like operating systems

The Unix operating system (as well as any other Unix-like operating system, which includes the various forms of Linux, UBUNTU, Free BSD Unix, and Mac OS X) is commonly used in the exploration seismic community. Consequently, learning aspects of this operating system is time well spent. Many users may have grown up with a “point and click” environment (or a “there is an app for that” environment), where a given program is run via a graphical user interface (GUI) featuring menus and assorted windows. Certainly there are such software applications in the world of commercial seismic processing, but none of these are inexpensive, and none give the user access to the source code of the application.

There is also an “expert user” level of work where such GUI-driven tools do not exist and programs are run from the commandline of a terminal window or are executed as part of a processing sequence in shell script.

In this course we will use the open source CWP/SU:Seismic Unix (called simply Seismic Unix or SU) seismic processing and research environment. This software collection was developed largely at the Colorado School of Mines (CSM) at the Center for Wave Phenomena (CWP), with contributions from users all around the world. The SU software package is designed to run under any Unix or Unix-like operating system, and is available as full source code. Students are free to install Linux and SU on their PCs (or use Unix-like alternatives) and thus have the software as well as the data provided for the course for home use, during, and beyond the time of the course.

The datasets are also open. The major dataset that we will use in the course was put in the public domain by Mobil corporation in the early 1990s. The student may have both the data and the software for his/her own continuing education after the course is finished.

1.2.1 Steep learning curve

The disadvantage that most beginning Unix users face is a steep learning curve owing to the myriad commands that comprise Unix and other Unix-like operating systems. The advantages of software portability and flexibility of applications, as well as superior networking capability, however, makes Unix more attractive to industry than Microsoft-based systems for these expert level applications. While a user in an industrial environment may have a Microsoft-based PC on his or her desk, the more computationally intensive processing work is done on a Unix-based system. The largest of these are clusters composed of multi-core, multiprocessor PC systems. It is not uncommon these days for such systems to have several thousand “cores,” which is to say subprocessors. Thus, massive parallelism is available in the industry environment.

Because a course in seismic processing is of broad interest and may draw students with varied backgrounds and varied familiarity with computing systems, we begin with the basics. The reader familiar with these topics may skip to the next chapter.
1.3 Logging in

As with most computer systems, there is a prompt, usually containing the word "login" or the word "username" that indicates the place where the user types his or her login name. The user is then prompted for a password. Once on the system, the user either has a windowed user interface as the default, or initiates such an interface with a command, such as `startx` in some installations of Linux.

(If you are unable to login on the laboratory machines, you likely need to set your CSM MultiPass password. For this you will need your Colorado School of Mines E-Key, which you obtained when you registered at the school.)

1.4 What is a Shell?

Some of the difficult and confusing aspects of Unix and Unix-like operating systems are encountered at the very beginning of using the system. The first of these is the notion of a shell. Unix is an hierarchical operating system that runs a program called the kernel that is the heart of the operating system. Everything else consists of programs that are run by the kernel and which give the user access to the kernel and thus to the hardware of the machine.

The program that allows the user to interface with the computer is called the “working shell.” The basic level of shell on all Unix systems is called `sh`, the Bourne shell. Under Linux-based systems, this shell is actually an open-source rewritten version called `bash` (the Bourne again shell), but it has an alias that makes it appear to be the same as the `sh` that is found on all other Unix and Unix-like systems.

The common working shell environment that a user is usually set up to login in under may be `csh` (the C-shell), `tcsh` (the T-shell, which is a non proprietary version of `csh`, `ksh` (the Korn shell, which is proprietary), `zsh` which is an open source version of Korn shell, or `bash`, which is an open source version of the Bourne shell.

On Linux and Mac OS X systems `bash` is the default shell environment.

The user has access to an application called `terminal` in the graphical user environment, that when launched (usually by double clicking on an icon that looks like a small video monitor) invokes a window called a `terminal window`. (The word “terminal” harks back to an earlier day, when a physical device called a ”terminal,” a screen and keyboard (but no mouse), constituted the users’ interface to the computer.) It is at the prompt on the terminal window that the user has access to a `commandline` where Unix commands are typed.

Most “commands” on Unix-like systems are not built in commands in the shell, but are actually programs that are run under the users’ working shell environment. The shell commandline prompt is asking the user to input the name of an executable program. That program may be a system command, such as a directory (folder) listing, or it may be a program written by a third party, or by the user him/herself.
1.5 The working environment

In the Unix world all filenames, program names, shells, and directory names, as well as passwords are case sensitive in their input, so please be careful in running the examples that follow.

If the user types:

$ cd
^takes the user to his/her home directory
(don’t type the dollar sign)

In these notes, the $ symbol will represent the commandline prompt. The user does not type this $$. Because there are a large variety of possible prompt characters, or strings of characters that people use for the propmt, we show here only the dollar sign $ as a generic commandline prompt. On your system it might be a %, a >, or some combination of these with the computer name and or the working directory and/or the commandline number.

$ echo $SHELL
^returns the value of the users’ working shell environment
type this dollar sign

The command echo $SHELL tells your working shell to return the value that denotes your working shell environment. In English this command might be translated as “print the value of the variable SHELL”. In this context the dollar sign $ in front of SHELL should be translated as “value of”. Thus, ”echo value of SHELL”.

Common possible shells are

/bin/sh $<--- the Bourne Shell
/bin/bash $<--- the Bourne again Shell
/bin/ksh $<--- K-shell
/bin/zsh $<--- Z-shell
/bin/csh $<--- C-shell
/bin/tcsh $<--- T-shell.

The environments sh, bash, ksh, and zsh are similar. We will call these the “sh-family.” The environments csh and tcsh are similar to each other, but have many differences from the sh-family. We refer to csh and tcsh as the csh-family.

Again, on Linux and Mac OX systems /bin/bash is usually the default working shell environment.
1.6 Setting the working environment

Each of these programs have a specific syntax, which can be quite complicated. Each is a language that allows the user to write programs called “shell scripts.” Thus Unix-like systems have scripting languages as their basic interface environment. This endows Unix-like operating systems with vastly more flexibility and power than other operating systems you may have encountered, only as point and click environments. Even those environments may have a shell command structure that the user is protected from by a windowed environment.

Why have such a structure? The answer is that “point and click is not enough.” The expert user needs to be able to provide more complicated instructions to the computer, and the shell provides the language of those instructions.

With more flexibility and power, there comes more complexity. It is possible to perform many configuration changes and personalizations to your working environment, which can enhance your user experience. For these notes we concentrate only on enough of these to allow you to work effectively on the examples in the text.

1.7 Choice of editor

To edit files on a Unix-like system the user must adopt an editor. The traditional Unix editor is vi or one of its non-proprietary clones vim (vi-improved), gvim, or elvis. The vi environment has a steep learning curve making it often unpopular among beginners. If a person is envisioning working on Unix-like systems a lot, then taking the time to learn vi is also time well spent. The vi editor is the only editor that is guaranteed to be on all Unix-like systems. All other editors are third-party items that may have to be added on some systems, sometimes with difficulty.

Similarly there is an editor called emacs that is popular among many users, largely because it is possible to write programs in the LISP language and implement these within the emacs environment. There is also a steep learning curve for this language. There is often substantial configuration required to get emacs working in the way the user desires.

A third editor is called pico, which comes with a mailer called “pine.” Pico is easy to learn to use, fully menued, and runs in a terminal window.

The fourth class of editor consists of the “screen editors.” Popular screen editors include xedit, nedit, and gedit. There is a windowed interfaced version of emacs called xemacs that is similar to the first two editors. These are all easy to learn and to use.

Not all editors are the best to use. The user may find that invisible characters are introduced by some editors, and that there may be issues regarding how wrapped lines are handled that may cause problems for some applications. These issues are another incentive for an expert user, such as a Unix system administrator to prefer vi over other more intuitive editors.

The choice of editor is often a highly personal one depending on what the user is familiar with, or is trying to accomplish. Any of the above mentioned editors, or similar
Vi Quick Reference

http://www.sfu.ca/~yzhang/linux

MOVEMENT

By Character
- k
- h <- mitochondrial 
- j

By Line
- nG to line n
- 0, $ first, last position on line
- ^ or _ first non-whitespace char on line
- +, - first character on next, prev line

By Screen
- ^F, ^B scroll forward, back one full screen
- ^D, ^U scroll forward, back half a screen
- ^E, ^Y show one more line at bottom, top
- L go to the bottom of the screen
- z,J position line with cursor at top
- z. position line with cursor at middle
- z- position line with cursor at

Marking Position on Screen
- mp mark current position as p (a...z)
- `p move to mark position p
- ^p move to first non-whitespace on line w/mark p

Miscellaneous Movement
- lm forward to character m
- Em backward to character m
- Tm backward to character after m
- w move to next word (stops at punctuation)
- W move to next word (skips punctuation)
- b move to previous word (stops at punctuation)
- B move to previous word (skips punctuation)
- e end of word (punctuation not part of word)
- E end of word (punctuation part of word)
- ), ( next, previous sentence
- ]], [ next, previous section
- }, { next, previous paragraph
- % goto matching parenthesis () {}, []

EDITING TEXT

Entering Text
- a append after cursor
- A or $a append at end of line
- i insert before cursor
- I or _i insert at beginning of line
- o open line below cursor
- O open line above cursor
- cm change text (n is movement)

Cut, Copy, Paste (Working w Buffers)
- dm delete (m is movement)
- dd delete line
- D or d$ delete to end of line
- x delete char under cursor
- X delete char before cursor
- ym yank to buffer (m is movement)
- yy or Y yank to buffer current line
- p paste from buffer after cursor
- P paste from buffer before cursor
- ^bdp cut line into named buffer b (a...z)
- ^bp paste from named buffer b

Searching and Replacing
- /w search forward for w
- ?w search backward for w
- /w+n search forward for w and move down n lines
- n repeat search (forward)
- N repeat search (backward)

-fore / old/new replace next occurrence of old with new
-fore / old/new/g replace all occurrences on the line
-fore / x/y/old/new/g replace all occurrences from line x to y
-fore / old/new/g replace all occurrences in file
-fore / old/new/gc same as above, with confirmation

Miscellaneous
- m-m indent n lines (m is movement)
- u-m un-indent left n lines (m is movement)
- . repeat last command
- U undo changes on current line
- u undo last command
- J join end of line with next line (at <CR>)
- xf insert text from external file f
- ^G show status

Figure 1.1: A quick reference for the vi editor.
third party editors likely are sufficient for the purposes of this course.

For this class, if you are not already familiar with vi or some other editor, I would recommend using gedit.

1.8 The Unix directory structure

As with other computing systems, data and programs are contained in “files” and “files” are contained in “folders.” In Unix and all Unix-like environments “folders” are called “directories.”

The structure of directories in Unix is that of an upside down tree, with its root at the top, and its branches—subdirectories and the files they contain—extending downward. The root directory is called “/” (pronounced “slash”).

While there exist graphical browsers on most Unix-like operating systems, it is more efficient for users working on the commandline of a terminal windows to use a few simple commands to view and navigate the contents of the directory structure. Some of these commands are pwd (print working directory), ls (list contents), and cd (change directory).

Locating yourself on the system

If you type:

```
$ cd
$ pwd
$ ls
```

You will see your current working directory location, which is your called your “home directory.” You should see something like

```
$ pwd
/home/yourusername
```

where “yourusername” is your username on the system. Other users likely have their home directories in

```
/home
```

or something similar depending on how your system administrator has set things up. The command ls (which is short for ”list”) will show you the contents of your home directory, which may consist of files or other subdirectories.

The codes for Seismic Unix are installed in some system directory path. We will assume that all of the CWP/SU: Seismic Unix codes are located in

```
/usr/local/cwp
```
This denotes a directory “cwp,” which is the sub directory of a directory called “local,” which is in turn is a subdirectory of the directory “usr,” that itself is a sub directory of slash.

It is worthwhile for the user to spend some time learning the layout of his or her directories. There is a command called

$ df

which shows the hardware devices that constitute the available storage on the users’ machine. A typical output from typing “df”

$ df -h

<table>
<thead>
<tr>
<th>Filesystem</th>
<th>Size</th>
<th>Used</th>
<th>Avail</th>
<th>Use%</th>
<th>Mounted on</th>
</tr>
</thead>
<tbody>
<tr>
<td>/dev/sda1</td>
<td>286G</td>
<td>19G</td>
<td>253G</td>
<td>7%</td>
<td>/</td>
</tr>
<tr>
<td>none</td>
<td>4.0K</td>
<td>0</td>
<td>4.0K</td>
<td>0%</td>
<td>/sys/fs/cgroup</td>
</tr>
<tr>
<td>udev</td>
<td>3.9G</td>
<td>4.0K</td>
<td>3.9G</td>
<td>1%</td>
<td>/dev</td>
</tr>
<tr>
<td>tmpfs</td>
<td>795M</td>
<td>1.1M</td>
<td>794M</td>
<td>1%</td>
<td>/run</td>
</tr>
<tr>
<td>none</td>
<td>5.0M</td>
<td>0</td>
<td>5.0M</td>
<td>0%</td>
<td>/run/lock</td>
</tr>
<tr>
<td>none</td>
<td>3.9G</td>
<td>488K</td>
<td>3.9G</td>
<td>1%</td>
<td>/run/shm</td>
</tr>
<tr>
<td>none</td>
<td>100M</td>
<td>44K</td>
<td>100M</td>
<td>1%</td>
<td>/run/user</td>
</tr>
<tr>
<td>fermat:/u</td>
<td>2.0T</td>
<td>1.3T</td>
<td>664G</td>
<td>66%</td>
<td>/u</td>
</tr>
<tr>
<td>fermat:/gpfc</td>
<td>3.0T</td>
<td>1.1T</td>
<td>1.8T</td>
<td>38%</td>
<td>/gpfc</td>
</tr>
<tr>
<td>isengard:/class</td>
<td>15G</td>
<td>562M</td>
<td>14G</td>
<td>4%</td>
<td>/class</td>
</tr>
<tr>
<td>isengard:/usr/local/cwp</td>
<td>20G</td>
<td>17G</td>
<td>2.2G</td>
<td>89%</td>
<td>/usr/local/cwp</td>
</tr>
<tr>
<td>isengard:/scratch</td>
<td>378G</td>
<td>270G</td>
<td>90G</td>
<td>76%</td>
<td>/scratch</td>
</tr>
<tr>
<td>isengard:/data</td>
<td>99G</td>
<td>52G</td>
<td>47G</td>
<td>56%</td>
<td>/data</td>
</tr>
<tr>
<td>isengard:/data/cwpscratch</td>
<td>30G</td>
<td>6.9G</td>
<td>22G</td>
<td>25%</td>
<td>/data/cwpscratch</td>
</tr>
</tbody>
</table>

Note items in the far left column. Those whose names that begin with “dev” are hardware devices on the specific computer. The items that begin with a machine name, in this case “isengard.mines.edu” exist physically on another machine (named “isengard”), but are remotely mounted as to appear to be on this machine. The second column from the left shows the total space on the device, the third column shows the amount of space used, while the fourth shows the amount available, the fifth column shows the usage as a percentage of space used. Finally the far right column shows the directory where these devices are mounted.

In Unix-like environments, devices are mounted in such a way that they appear to be files or directories. Under Unix-like operating systems, the user sees only a directory tree, and not individual hardware devices.

If you try editing files in some of these other directories you will find that you likely may not have permission to read, write, or modify the contents of many those directories. Unix is a multi-user environment, meaning that from an early day, the notion of
protecting users from each other and from themselves, as well as protecting the operating system from the users, has been a priority.

In none of these examples have we used a browser, yet there are browsers available on most Unix systems. There is no fundamental problem with using a browser, with the exception that you have to take your hands off the keyboard to use the mouse. The browser will not tell you where you are located within a terminal window. If you must use a browser, use “column view” rather than “icon view” as we will have many levels of nested directories to navigate.

1.9 Scratch and Data directories

Directories with names such as “scratch” and “data” are often provided with user write permission so that users may keep temporary files and data files out of their home directories. Like “scratch paper” a scratch directory is usually for temporary file storage, and is NOT BACKED UP! Indeed, on any computer system there may be other unbacked up directories. You need to be aware of which parts of your computer system are backed up and which are not. Because there are no backups on scratch directories, it is important for the user to purchase a USB device to back up his or her items from the scratch areas.

Some directories may be physically located on the specific machine were you are seated and may not be visible on other machines. Because the redundancy of backups require extra storage, most system administrators restrict the amount of backed up space to a relatively small area of a computer system. To restrict user access, quotas may be imposed that will prevent users from using so much space that a single user could fill up a disk. However, in scratch areas there usually are no such restrictions, so it is preferable to work in these directories, and save only really important materials in your home directory.

Users should be aware, that administration of scratch directories may not be user friendly. Using up all of the space on a partition may have dire consequences, in that the administrator may simply remove items that are too big, or have a policy of removing items that have not been accessed over a certain period of time. A system administrator may also set up an automated “grim file reaper” to automatically delete materials that have not been accessed after a period of time. Because files are not always automatically backed up, and because hardware failures are possible on any system, it is a good idea for the user to purchase USB storage media and get in the habit of making personal backups on a regular basis. A less hostile mode of management is to institute quotas to prevent single users from hogging the available scratch space.

You may see a scratch directory on any of the machines in your lab, but these are different directories, each located on a different hard drive. This can lead to confusion as a user may copy stuff into a scratch area on one day, and then work on a different computer on a different day, thinking that their stuff has been removed.

The availability and use of scratch directories is important, because each user has a quota that limits the amount of space that he or she may use in his/her home directory.
On systems where a scratch directory is provided, that also has write permission, the user may create his/her personal work area via

```
$ cd /scratch
$ mkdir yourusername  
<--- here "yourusername" is the your user name on the system
```

Unless otherwise stated, this text will assume that you are conducting further operations in your personal scratch work area.

For our system, the scratch directory that we will work in is gpfc so your instructions are to

```
$ cd /gpfc
$ mkdir yourusername  
<--- here "yourusername" is the your user name on the system
```

The directory gpfcyourusername will be your preferred scratch or working area.

### 1.10 Shell environment variables and path

The working shell is a program that has a configuration that gives the user access to executable files on the system. Recall that echoing the value of the SHELL variable

```
$ echo $SHELL  
<--- returns the value of the users’ working shell environment
```

tells you what shell program is your working shell environment. There are other environmental variables other than SHELL. Again, note that if this command returns one of the values

```
/bin/sh  
/bin/ksh  
/bin/bash  
/bin/zsh
```

then you are working in the SH-family and need to follow instructions for working with that type of environment. If, on the other hand, the `echo $SHELL` command returns one of the values

```
/bin/csh  
/bin/tcsh
```

then you are working in the CSH-family and need to follow the alternate series of instructions given.

In the modern world of Linux, it is quite common for the default shell to be something called binbash an open-source version of binsh.
1.10.1 The path or PATH

Another important variable is the “path” or “PATH”. The value path variable tells the location that the working shell looks for executable files in. Usually, executables are stored in a sub directory “bin” of some directory. Because there may be many software packages installed on a system, there may be many such locations.

To find out what paths you can access, which is to say, which executables your shell can see, type

```bash
$ echo $path
```

or

```bash
$ echo $PATH
```

The result will be a listing, separated by colons “:” of paths or by spaces “ ” to executable programs.

1.10.2 The CWPROOT variable

The variable PATH is important, but SHELL and PATH are not the only possible environment variable. Often programmers will use an environment variable to give a users’ shell access to some attribute or information regarding a specific piece of software. This is done because sometimes software packages are of restricted interest.

For SU the path CWPROOT is necessary for running the SU suite of programs. We need to set this environment variable, and to put the suite of Seismic Unix programs on the users’ path.

1.11 Shell configuration files

Because the users’ shell has as an attribute a natural programming language, many configurations of the shell environment are possible. To find the configuration files for your operating system, type

```bash
$ ls -a       # show directory listing of all files and sub directories
$ pwd        # print working directory
```

then the user will see a number of files whose names begin with a dot “.”.

1.12 Setting up the working environment

One of the most difficult and confusing aspects of working on Unix-like systems is encountered right at the beginning. This is the problem of setting up user’s personal environment. There are two sets of instructions given here. One for the CSH-family of shells and the other for the SH-family.
1.12.1 The CSH-family

Each of the shell types returned by $SHELL has a different configuration file. For the csh-family (tcsh,csh), the configuration files are “.cshrc” and “.login”. To configure the shell, edit the file .cshrc. Also, the “path” variable is lower case.

You will likely find a line beginning with

```c
set path=(
```

with entries something like

```c
set path=( /lib ~/bin /usr/bin/X11 /usr/local/bin /bin
 /usr/bin . /usr/local/bin /usr/sbin )
```

Suppose that the Seismic Unix package is installed in the directory

```
/usr/local/cwp
```

on your system.

Then we would add one line above to set the “CWPROOT” environment variable. And one line below to define the user’s “path”

```c
setenv CWPROOT /usr/local/cwp
```

```c
set path=( /lib ~/bin /usr/bin/X11 /usr/local/bin /bin
 /usr/bin . /usr/local/bin /usr/sbin )
```

```c
set path=( $path $CWPROOT/bin )
```

Save the file, and log out and log back in. You will need to log out completely from the system, not just from particular terminal windows.

When you log back in, and pull up a terminal window, typing

```bash
$ echo $CWPROOT
```

will yield

```
/usr/local/cwp
```

and

```bash
$ echo $PATH
```

will yield

```
/lib /u/yourusername/bin /usr/bin/X11 /usr/local/bin /bin
 /usr/bin . /usr/local/bin /usr/sbin /usr/local/cwp/bin
```
1.12.2 The SH-family

The process is similar for the SH-family of shells. The file of interest has a name of the form “.profile,” .bashrc,” and the “.bash_profile.” The “.bash_profile” is read once by the shell, but the “.bashrc” file is read everytime a window is opened or a shell is invoked. (Or vice versa, depending on the system. Mac OS X seems to have a strange convention.) Thus, what is set here influences the users complete environment. The default form of this file may show a path line similar to

```bash
PATH=$PATH:$HOME/bin:.:/usr/local/bin
```

which should be edited to read

```bash
export CWROOT=/usr/local/cwp
PATH=$PATH:$HOME/bin:/usr/local/bin:$CWROOT/bin:.
```

The important part of the path is to add the

```bash
:$CWROOT/bin:.
```

on the end of the PATH line, no matter what it says.

The user then logs out and logs back in for the changes to take effect. In each case, the PATH and CWROOT variables are necessary to be set for the users’ working shell environment to find the executables of Seismic Unix.

1.13 Unix help mechanism- Unix man pages

Every program on a Unix or Unix-like system has a system manual page, called a man page, that gives a terse description of its usage. For example, type:

```bash
$ man ls
$ man cd
$ man df
$ man sh
$ man bash
$ man csh
```

to see what the system says about these commands. For example:

```bash
$ man ls
```

```text
LS(1) User Commands
```

```text
NAME
ls - list directory contents
```
SYNOPSIS
   ls [OPTION]... [FILE]...

DESCRIPTION
   List information about the FILEs (the current directory by default).
   Sort entries alphabetically if none of -cftuvSU nor --sort.

   Mandatory arguments to long options are mandatory for short options too.

   -a, --all
       do not ignore entries starting with .

   -A, --almost-all
       do not list implied . and..

--MORE--

The item at the bottom that says –MORE– indicates that the page continues. To see
the rest of the man page for ls is viewed by hitting the space bar. View the Unix man
page for each of the Unix commands you have used so far.

   Most Unix commands have options such as the ls -a which allowed you to see files
beginning with dot “.” or ls -l which shows the “long listing” of programs. Remember
to view the Unix man pages of each new Unix command as it is presented.

References

   Sobell, M. (2010), “A practical guide to Linux commands, editors, and shell program-
ming” Pearson Education Inc., Boston, MA.
Any program that has executable permissions and which appears on the users' PATH may be run by simply typing its name on the commandline. For example, if you have set your path correctly, you should be able to do the following:

```
$ suplane | suxwigb &
```

The "pipe" symbol

This symbol, the ampersand, indicates that
the program is being run in background

The commandline itself is the interactive prompt that the shell program is providing so that you can supply input. The proper input for a commandline is an executable file, which may be a compiled program or a Unix shell script. The command prompt is saying, "Type program name here."

Try running this command with and without the ampersand &. If you run:

```
$ suplane | suxwigb
```

The plot comes up, but you have to kill the plot window before you can get your commandline back, whereas:

```
$ suplane | suxwigb &
```

allows you to have the plot on the screen, and have the commandline.

To make the plot better we may add some axis labeling:

```
$ suplane | suxwigb title="suplane test pattern"
label1="time (s)" label2="trace number" &
```

Here the command is broken across a line
so it will fit this page of this book.
On your screen it would be typed as one long line.
Figure 2.1: The suplane test pattern.
to see a test pattern consisting of three intersecting lines in the form of seismic traces. The data consist of seismic traces with only single values that are nonzero. This is variable area display in which each place where the trace is positive valued is shaded black. See Figure 2.1.

Equivalently, you should see the same output by typing

```
$ suplane > junk.su
$ suxwigb < junk.su title="suplane test pattern"
    label1="time (s)" label2="trace number" &
```

Finally, we often need to have graphical output that can be imported into documents. In SU we have graphics programs that write output in the PostScript language

```
$ supswigb < junk.su title="suplane test pattern"
    label1="time (s)" label2="trace number" > suplane.eps
```

### 2.1 Pipe |, redirect in <, redirect out >, and run in background &

In the commands in the last section we used three symbols that allow files and programs to send data to each other and to send data between programs. The vertical bar | is called a “pipe” on all Unix-like systems. Output sent to standard out may be piped from one program to another program as was done in the example of

```
$ suplane | suxwigb &
```

which, in English may be translated as “run *suplane* (pipe output to the program) *suxwigb* where the & says (run all commands on this line in background).” The pipe | is a memory buffer with a “read from standard input” for an input and a “write to standard output” for an output. You can think of this as a kind of plumbing. A stream of data, much like a stream of water is flowing from the program *suplane* to the program *suxwigb*.

The “greater than” sign > is called “redirect out” and

```
$ suplane > junk.su
```

says ”run *suplane* (writing output to the file) junk.su. The > is a buffer which reads from standard input and writes to the file whose name is supplied to the right of the symbol. Think of this as data pouring out of the program *suplane* into the file junk.su.

The “less than” sign < is called “redirect in” and

```
$ suxwigb < junk.su &
```

says ”run *suxwigb* (reading the input from the file ) junk.su (run in background).

- | = pipe from program to program
Figure 2.2: a) The suplane test pattern. b) the Fourier transform (time to frequency) of the suplane test pattern via suspecfx.

- > = write data from program to file (redirect out)
- < = read data from file to program (redirect in)
- & = run program in background

2.2 Stringing commands together

We may string together programs via pipes (|), and input and output via redirects (>) and (<). An example is to use the program suspecfx to look at the amplitude spectrum of the traces in data made with suplane:

```
$ suplane | suspecfx | suxwigb & --make suplane data, find the amplitude spectrum, plot as wiggle traces
```

Equivalently, we may do

```
$ suplane > junk.su --make suplane data, write to a file.
$ suspecfx < junk.su > junk1.su --find the amplitude spectrum, write to a file.
$ suxwigb < junk1.su & -- view the output as wiggle traces.
```

This does exactly the same thing, in terms of final output as the previous example, with the exception that here, two files have been created. See Figure 2.2.
2.2.1 Questions for discussion

- What is the Fourier transform of a function?
- What is an amplitude spectrum?
- Why do the plots of the amplitude spectrum in Figure 2.2 appear as they do?

2.3 Unix Quick Reference Cards

The two figures, Fig 2.3 and Fig 2.4 are a Quick Reference cards for some Unix commands

References

Working with NFS files

Files saved on the UITS central Unix computers Chrome, Cobalt, Zinc, Steel, EZinfo, and STARSS SP are stored on the Network File Server (NFS). That means that your files are really on one disk, in directories named for the central Unix hosts on which you have accounts.

No matter which of these computers you are logged into, you can get to your files on any of the others. Here are the commands to use to get to any system directory from any other system:

`cd /username/Chrome/`
`cd /username/Cobalt/`
`cd /username/Zinc/`
`cd /username/Steel/`
`cd /username/EZinfo/`
`cd /username/STARSS SP/`

Be sure you use the capitalization just as you see above, and substitute your own username for `username`.

For example, if Jessica Rabbit is logged into her account on Steel, and wants to get a file on her EZinfo account, she would enter:

`cd /jusrabbit/EZinfo/`

Now when she lists her files, she'll see her EZinfo files, even though she's actually logged into Steel.

You can use the ordinary Unix commands to move files, copy files, or make symbolic links between files. For example, if John Doe wanted to move "file1" from his Steel directory to his EZinfo directory, he would enter:

`mv -i /jusrabbit/Steel/file1 /jusrabbit/EZinfo/`

This shared file system means that you can access, for example, your Chrome files even when you are logged into Cobalt, and vice versa. However, if you are logged into Chrome, you can only use the software installed on Chrome — only users' directories are linked together, not system directories.

Unix commands reference card

August 1998

To access this guide on the World Wide Web, set your browser to http://www.indiana.edu/~uitspubs/017/
### Environment Control

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>cd</td>
<td>Change to directory</td>
</tr>
<tr>
<td>mkdir</td>
<td>Create new directory</td>
</tr>
<tr>
<td>mv</td>
<td>Move file to directory</td>
</tr>
<tr>
<td>rm</td>
<td>Remove directory</td>
</tr>
<tr>
<td>passwd</td>
<td>Change password</td>
</tr>
<tr>
<td>alias</td>
<td>Create command alias</td>
</tr>
<tr>
<td>man</td>
<td>Manual command alias</td>
</tr>
<tr>
<td>log</td>
<td>Retrieve session</td>
</tr>
<tr>
<td>setenv</td>
<td>Set environment variable</td>
</tr>
<tr>
<td>unsetenv</td>
<td>Remove environment variable</td>
</tr>
</tbody>
</table>

### Output, Communication, & Help

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>lpr-P</td>
<td>Output file to line printer</td>
</tr>
<tr>
<td>script</td>
<td>Start script session</td>
</tr>
<tr>
<td>logout</td>
<td>Exit terminal session</td>
</tr>
<tr>
<td>mail</td>
<td>Send mail to user</td>
</tr>
<tr>
<td>man</td>
<td>Display man page information for UNIX command</td>
</tr>
<tr>
<td>name</td>
<td>Online tutorial</td>
</tr>
</tbody>
</table>

### Process Control

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ctrl+c</td>
<td>Interrupt processes</td>
</tr>
<tr>
<td>Ctrl+k</td>
<td>Stop screen scrolling</td>
</tr>
<tr>
<td>sleep</td>
<td>Sleep for n seconds</td>
</tr>
<tr>
<td>jobs</td>
<td>Print list of jobs</td>
</tr>
<tr>
<td>kill</td>
<td>Kill job n</td>
</tr>
<tr>
<td>ps</td>
<td>Print process status</td>
</tr>
<tr>
<td>kill -9</td>
<td>Remove process n</td>
</tr>
<tr>
<td>Ctrl+z</td>
<td>Resume current process</td>
</tr>
<tr>
<td>stop</td>
<td>Resume background job n</td>
</tr>
<tr>
<td>command</td>
<td>Resume command background</td>
</tr>
<tr>
<td>bg</td>
<td>Resume background job n</td>
</tr>
<tr>
<td>fg</td>
<td>Resume foreground job n</td>
</tr>
<tr>
<td>exit</td>
<td>Exit from shell</td>
</tr>
</tbody>
</table>

### Environment Status

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ls [-1]</td>
<td>List files in directory</td>
</tr>
<tr>
<td>is [-1]</td>
<td>List files in current directory</td>
</tr>
<tr>
<td>alias</td>
<td>Display command aliases</td>
</tr>
<tr>
<td>printenv</td>
<td>Display environment values</td>
</tr>
<tr>
<td>who</td>
<td>Display current user</td>
</tr>
<tr>
<td>whodir</td>
<td>Display home directory</td>
</tr>
<tr>
<td>finger</td>
<td>Display fingerprint</td>
</tr>
<tr>
<td>chfn</td>
<td>Change fingerprint</td>
</tr>
<tr>
<td>pwd</td>
<td>Display working directory</td>
</tr>
<tr>
<td>history</td>
<td>Display recent commands</td>
</tr>
</tbody>
</table>

### File Manipulation

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>vi</td>
<td>Use vi editor</td>
</tr>
<tr>
<td>emacs</td>
<td>Use emacs editor</td>
</tr>
<tr>
<td>ed</td>
<td>Use ed editor</td>
</tr>
<tr>
<td>wc</td>
<td>Count lines, words, &amp; characters</td>
</tr>
<tr>
<td>ls</td>
<td>List contents of file</td>
</tr>
<tr>
<td>more</td>
<td>Display file contents by screen</td>
</tr>
<tr>
<td>cat</td>
<td>Write contents of file to screen</td>
</tr>
<tr>
<td>cmp</td>
<td>Compare two files</td>
</tr>
<tr>
<td>cp</td>
<td>Copy file to another file</td>
</tr>
<tr>
<td>sort</td>
<td>Alphabetically sort files</td>
</tr>
<tr>
<td>split</td>
<td>Split files into n pieces</td>
</tr>
<tr>
<td>mv</td>
<td>Move file to another file</td>
</tr>
<tr>
<td>rm</td>
<td>Remove file</td>
</tr>
<tr>
<td>grep</td>
<td>Remove occurrence</td>
</tr>
<tr>
<td>diff</td>
<td>Display file differences</td>
</tr>
<tr>
<td>head</td>
<td>Display beginning of file</td>
</tr>
<tr>
<td>tail</td>
<td>Display end of file</td>
</tr>
</tbody>
</table>

### Compiler

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>cc [-o]</td>
<td>Compiler</td>
</tr>
<tr>
<td>ln [-f]</td>
<td>Check &amp; code for errors</td>
</tr>
<tr>
<td>f77 [-o]</td>
<td>Fortran77 compiler</td>
</tr>
<tr>
<td>pw [-o]</td>
<td>Pascal compiler</td>
</tr>
</tbody>
</table>
Chapter 3

Lab Activity #2 - viewing data

Just as scratch paper is paper that you use temporarily without the plan of saving for the long term, a “scratch directory” is temporary working space, which is not backed up and which may be arbitrarily cleared by the system administrator. Each computer in this lab has a directory called /scratch that is provided as a temporary workspace for users. It is in this location that you will be working with data. Create your own scratch directory via:

$ mkdir /gpfc/yourusername

Here “yourusername” is the actual username that you are designated as on this system. Please feel free to ask for help as you need it.

The /gpfc directory may reside physically on the computer where you are sitting, or it may be remotely mounted. In computer environments where the directory is locally on the a given computer, you will have to keep working on the same system. If you change computers, you will have to transfer the items from your personal scratch area to that new machine. In labs where the directory is remotely mounted, you may work on any machine that has the directory mounted.

Remember: /scratch directories are not backed up. If you want to save materials permanently, it is a good idea to make use of a USB storage device.

3.0.1 Data image examples

Three small datasets are provided. These are labeled “sonar.su,” “radar.su,” and “seismic.su” and are located in the directory

/data/cwpscratch/Data1/

We will pretend that these data examples are “data images,” which is to say these are examples that require no further processing.

Do the following:

$ cd /gpfc/yourusername (this takes you to /gpfc/yourusername)
3.1 Viewing an SU data file: Wiggle traces and Image plots

Though we are assuming that the examples \texttt{sonar.su}, \texttt{seismic.su}, and \texttt{radar.su} are finished products, our mode of presentation of these datasets may change the way we view them entirely. Proper presentation can enhance features we want to see, suppress parts of the data that we are less interested in, accentuate signal and suppress noise. Improper presentation, on the other hand, can take turn the best images into something that is totally useless.

3.1.1 Wiggle traces

A common mode of presentation of seismic data is the “wiggle trace.” Such a representation consists of representing the oscillations of the data as a graph of amplitude as a function of time, with successive traces plotted side-by-side. Amplitudes of one polarity (usually positive) are shaded black, whereas negative amplitudes are not shaded. Be aware that such presentation introduces a bias in the way we view the data, accentuating the positive amplitudes. Furthermore, wiggle traces may make dipping structures appear fatter than they actually are owing to the fact that a trace is a vertical slice through the data.

In SU we may view a wiggle trace display of data via the program \texttt{suxwigb}. For example, viewing the \texttt{sonar.su} data as wiggle traces is done by “redirecting in” the data file into “suxwigb”

\begin{verbatim}
$ suxwigb < sonar.su

done.
\end{verbatim}
The ampersand (&) means "run in background" so you get your commandline back.

This should look horrible! The problem is that there are 584 wiggle traces, side by side. Place the cursor on the plot and drag, while holding down the index finger mouse button. This is called a "rubberband box." Try grabbing a strip of the data of width less than 100 traces, by placing the cursor at the top line of the plot, and holding the index finger mouse button while dragging to the lower right. Zooming in this fashion will show wiggles. The less on here is that you need a relatively low density of data on your print medium for wiggle traces.

Place the mouse cursor on the plot, and type "q" to kill the window.

Try the seismic.su and the radar.su data as wiggle traces via:

$ suxwigb < seismic.su &
$ suxwigb < radar.su &

In each case, zoom in on the data until you are able to see the oscillations of the data.

3.1.2 Image plots

The seismic data may be thought of as an array of floating point numerical values, each representing a seismic amplitude at a specific \((t, x)\) location. A plot consisting of an array of gray or color dots, with each gray level or color representing the respective value is called an "image" plot.

If we view an alternative is an image plot:

$ suximage < sonar.su &

This should look better. We usually use image plots for datasets of more than 50 traces. We use wiggle traces for smaller datasets.

3.2 Greyscale

There are only 256 shades of gray available in this plot. If a single point in the dataset makes a large spike, then it is possible that most of the 256 shades are used up by that one amplitude. Therefore scaling amplitudes is often necessary. The simplest processing of the data is to amplitude truncate ("clip") the data. (The term "clip" refers to old time strip chart records, which when amplitudes were too large appeared if someone had taken scissors and clipped of the tops of the sinusoids of the oscillations.) Try:

$ suximage < sonar.su perc=99 &
$ suximage < sonar.su perc=99 legend=1

The perc=99 passes only those items of the 99th percentile and below in amplitude. (You may need to look up "percentile" on the Internet.) In other words, it "clips" (amplitude truncates) the data to remove the top 1 per cent of amplitudes. Try different values of "perc" to see what this does.
Figure 3.1: Image of `sonar.su` data (no perc). Only the largest amplitudes are visible.
Figure 3.2: Image of \texttt{sonar.su} data with perc=99. Clipping the top 1 percentile of amplitudes brings up the lower amplitude amplitudes of the plot.
3.3 Legend; making grayscale values scientifically meaningful

To be scientifically useful, which is to say “quantitative” we need to be able to translate shades of gray into numerical values. This is done via a gray scale, or “legend”. A “legend” is a scale or other device that allows us to see the meanings of the graphical convention used on a plot. Try:

$ suximage < sonar.su legend=1 &$

This will show a grayscale bar.

There are a number of colorscales available. Place the mouse cursor on the plot and press “h” you will see that further pressings of “h” will re plot the data in a different colorscale. Now press “r” a few times. The “h” scales are scales in “hue” and the “r” scales are in red-green-blue (rgb). It is important to see that the brightest part of each scale is chosen to emphasize a different amplitude.

With colormapping some parts of the plot may be emphasized at the expense of other parts. The issue of colormaps often is one of selecting the location of the “bright part” of the colorbar, versus darker colors. Even perfectly processed data may be rendered uninterpretable by a poor selection of colormapping. This effect may be seen in Figure 3.4.

Repeat the previous, this time clipping by percentile

$ suximage < sonar.su legend=1 perc=99 &$

The ease at which colorscales are defined, and the fact that there are no real standards on colorscales, mean that effectively every color plot you encounter requires a colorscale for you to be able to know what the values mean. Furthermore, some colors ranges are brighter than others. By moving the bright color to a different part of the amplitude range, you can totally change the image. This is a source of richness of display, but it is also a potential source of trouble, if the proper balance of color is not chosen.

3.4 Display balancing and display gaining

A common data amplitude balancing is to balance the colorscale on the median values in the data. The “median” is the middle value, meaning that half the values are larger than the median value and half the data are less than the median value. Thus, the traces are normalized by this middle value.

Another possibility is to scale traces by dividing by some constant value. For example dividing each trace by the square root of the average of the sum of the square of its values (RMS).

Type these commands to see that in SU:

$ sunormalize norm=balmed < sonar.su | suximage legend=1$
$ sunormalize norm=balmed < sonar.su | suximage legend=1 perc=99$
Figure 3.3: Image of \texttt{sonar.su} data with perc=99 and legend=1.
Figure 3.4: Comparison of the default, hsv0, hsv2, and hsv7 colormaps. Rendering these plots in grayscales emphasizes the location of the bright spot in the colorbar.
Figure 3.5: Image of \texttt{sonar.su} data with perc=99 and legend=1.
You may find `perc=99` to be useful. You may find that you have to apply an “RMS” balancing to make the data look a bit more uniform.

```
$ sunormalize norm=balmed < sonar.su |
    sunormalize norm=rms | suximage legend=1

$ sunormalize norm=balmed < sonar.su |
    sunormalize norm=rms | suximage legend=1 perc=99
```

Again, these commands are written as one long line, and are broken here to fit on the page. You may zoom in on regions of the plot you find interesting.

If you put both the median normalized and simple `perc=99` files on the screen side-by-side, there are differences, but these may not be striking differences. The program `suximage` has a feature that the user may change colormaps by pressing the “h” key or the “r” key. Try this and you will see that the selection of the colormap can make a considerable difference in the appearance of the image. Even with the same data, the colormap.

For example in Figure 3.7 we see the result of applying median balancing. We might consider applying `sunormalize` directly to the seismic data

```
$ suximage < seismic.su wbox=250 hbox=600 cmap=hsv4 clip=3 title="no median" &
```

compared with applying the median balancing

```
$ sunormalize norm=balmed < seismic.su |
    suximage wbox=250 hbox=600
cmap=hsv4 clip=3 title="median filtering" &
```

This result looks bizarre because the traces individually have different median values and consequently have different ranges of amplitudes. An improved picture may be obtained by applying an RMS normalization to the traces after they have been median filtered via,

```
$ sunormalize norm=balmed < seismic.su | sunormalize norm=rms |
    suximage wbox=250 hbox=600
cmap=hsv4 clip=3 title="median filtering" &
```

In each of these examples, the line is broken to fit on the page. When you type this, the pipe `|` follows immediately after the `seismic.su`.

There are other possibilities. We may consider simply normalizing the data by the maximum or minimum value, or by some other constant. Furthermore, we have the question of whether the process be applied trace by trace, or over the whole panel of data.
Figure 3.6: Image of `sonar.su` data with median balancing and perc=99
Figure 3.7: Comparison of **seismic**.su median-normalized, with the same data with no median balancing. Amplitudes are clipped to 3.0 in each case. Notice that there are features visible on the plot without median balancing that cannot be seen on the median normalized data.
3.5  Homework problem #1 - Due dates Thursday 3 Sept 2015 and Tuesday 8 September 2015

Repeat display gain experiments of the previous section with “radar.su” and “seismic.su” to see what median balancing, and setting perc=... does to these data.

- Capture representative plots with axes properly labeled. You can use the Linux screen capture feature, or find another way to capture plots into a file, (such as by using supsimage to make PostScript plots) Feel free to use different values of perc and different colormaps than were used in the previous examples. Is median filtering better? Is it worse? Can you simply change the clip value and get a better picture?

The OpenOffice (or LibreOffice) Word wordprocessing program is an easy program to use for this.

- Prepare a report of your results. The report should consist of:
  - Your plots (you are telling a story, show only images are relevant to your story)
  - a short paragraph describing what you saw. Think of it as a figure caption.
  - a listing of the actual commandlines that you ran to get the plots.
  - Not more than 3 pages total!
  - Make sure that your name, the due date, and the assignment number are at the top of the first page.

- Save your report in the form of a PDF file, and email to john@dix.mines.edu

3.6  Concluding Remarks

There are many ways of presenting data. Two of the most important questions that a scientist can ask when seeing a plot are ”What is the meaning of the colorscale or grayscale of a plot?” and ”What normalization or balancing has been applied to the data before the plot?” The answers to these questions may be as important as the answer to the question ”What processing has been applied to these data?”

3.6.1  What do the numbers mean?

The scale divisions seen on the plots in this chapter that have been obtained by running supsimage with legend=1 show numerical values, values that are changed when we apply display gain. Ultimately, these numbers relate to the voltage recorded from a transducer (a geophone, hydrophone, or accelerometer). While in theory we should be able to extract information about the size of the ground displacement in, say micrometers,
or the pressure field strength in, say *megapascals* there is little reason to do this. Owing to detector and source coupling issues, and the fact that data must be gathered quickly, we really are only interested in relative values.

**References**