Solutions to the exercises of Practical Seismic Data Analysis

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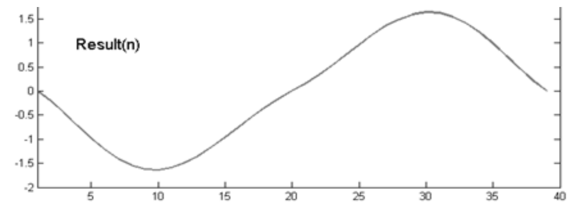
Disclaimer: This solution set provides some of the answers to the exercises that often have multitude of answers. Messages of NO STANDARD SOLUTION are given to some questions.

Sec	Question	Solution
2.1	1. Search the literature to find typical surface seismic survey geometry onshore and offshore, and the typical ranges of parameters such as source depths, receiver depths, source-to-receiver offsets, source-to-receiver azimuths, sample rates, data frequencies, and recording lengths. The results may be presented using a spreadsheet with clear citation of the references.	**Message of No STANDARD SOLUTION:** There are many published case studies showing acquisition geometry of seismic surveys onshore and offshore.
	2. Use your own words to define the concepts of: demultiplexing, time stack, matched filter, and walkaway RVSP.	Demultiplexing: A processing step that is similar to transposing in matrix operation. In other words, to switch the fast index from the channel number to time. Time stack: The process of summing multiple traces at the same location together along the horizontal axis, to simulate an image of subsurface in the time domain. Matched filter: A filter that maximized the output in response to a signal of particular shape. The elements of a matched filter are the elements of the signal in reverse order. It is also called cross-correlation filter. Walkaway VSP: A VSP survey in which the surface source moves laterally while the geophones in the borehole remain stationary.
	3. If we have multi-component surface reflection data, can we use a hodogram to suppress ground rolls? How would you do it? What problems can you anticipate for your approach?	It is possible to use the hodogram to suppress ground rolls because these Rayleigh waves have distinctly different polarization pattern from that of reflections which are the main data in reflection seismology. One approach is to analyze the different polarizations of the signal and ground rolls using hodograms, and then implement filters to separate the signal from noise such as ground rolls. Examples in the literature include the complex SVD-polarization filter (Kendall and Meersman, 2005) combined with localized *f-k* filtering (Meersman and Ansorger, 2007). We can expect several problems in suppressing ground rolls. The ground roll energy may spread out in the *f-k* domain due to aliasing or for data with out-of-line shots. The conversion between P and S waves may lead to phase differences between different components in the process.
2.2	1. Prove or refute the statement that stacking of seismic traces has the effect of low-pass filtering.	It is true that stacking of seismic traces has the effect of low-pass filtering. Stacking means summing the amplitudes of traces together. When two traces are in phase, a constructive interference will enhance the amplitude but no the frequency. When two traces are out of phase, the destructive interference will reduce the frequency.

<table>
<tr><td></td><td>2. Most semblance velocity analysis stacks all traces with equal weight. Should we apply variable weights as a function of offset and intersection time? Devise a way to conduct such a weighted semblance stack process. It would be great if you could write a program to realize the process.</td><td>There are two key elements in semblance velocity analysis, one is to recognize chief primary reflections based on the moveout pattern in the CMP gather, and the other is to maximize the SNR that relies more on the near-offset reflections. Because these two objectives have different sensitivities with respect to data in different offsets and varying intersection time, it will be more effective to apply variable weights as a function of offset and intersection time.
One way to implement weighting on offset is to have a vector of weighting coefficients of all data traces, and the effect is to rescale the amplitudes of data traces. The optimal values of the weighting vector can be obtained via modeling for each case. This idea can be easily programmed as a pre-processing step on the input data before the semblance velocity analysis.</td></tr>
<tr><td></td><td>3. The semblance velocities of multiple reflections are usually slower than the velocity of the primary reflection, as shown in Figure 2.8. Explain the reasons behind this observation.</td><td>At comparable reflection times the primary reflections penetrated at much greater depths than that of the multiple reflections, as shown in the inserted section of raypaths in Figure 2.8. Owing to the fact that velocity typically increases with depth, the semblance velocity of the primary reflections will be greater than that of the multiple reflections.
The above notion is the reason that, in semblance analysis, we shall try to pick the velocities along the higher velocity side of the semblance peaks.</td></tr>
<tr><td rowspan="3">2.3</td><td>1. Sketch the cross-correlation of two functions with equal time durations in Figure 2.13.(Hint: you may first discretize the functions into short time series, and then use the formula of discrete cross-correlation.)</td><td>We can discretize the two functions in Figure 2.13 into two short time series, and then apply the formula of discrete cross-correlation like Equation 2-22. An example sketch is shown here.

</td></tr>
<tr><td>2. Compare and contrast the convolution and cross-correlation operations. (Note: it may be best to organize your answer by using a table listing the similarities and differences.)</td><td>
<table>
<tr><th>Cross correlation</th><th>Convolution</th></tr>
<tr><td>It is the product of correlating two input signals. It indicates the similarity of those two waveforms as a function of a time-lag applied to one of them.</td><td>It is an integral that expresses the amount of overlap of one function as it is shifted over another function. I</td></tr>
<tr><td>It is not commutative.</td><td>It is commutative. It has same output no matter with array is moved/fixed.</td></tr>
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<tr><td>3. Cross-correlation is used to measure the similarity between two vectors $\mathbf{u} = (u_1, u_2, \ldots, u_N)^T$ and $\mathbf{v} = (v_1, v_2 \ldots, v_N)^T$. By removing the averages u_a and v_a, we obtain residual vectors $\Delta\mathbf{u} = (u_1 - u_a, u_2 - u_a, \ldots, u_N - u_a)^T$ and $\Delta\mathbf{v} = (v_1 - v_a, v_2 - v_a, \ldots, v_N - v_a)^T$. Is the cross-correlation between u and v the same as the cross-correlation between $\Delta\mathbf{u}$ and $\Delta\mathbf{v}$? Please explain your answer with evidence.</td><td>The cross-correlation between u and v may differ much from the cross-correlation between $\Delta\mathbf{u}$ and $\Delta\mathbf{v}$. The former depends on the averages of the vectors, while the latter measure the similarity between the two residual vectors.
As an example, when two velocity models look similar, their residual models after removing the average velocity models may differ much.</td></tr>
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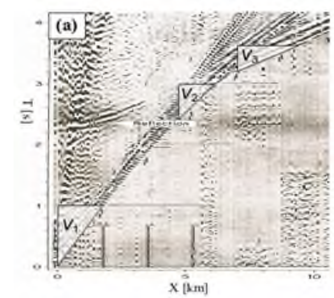
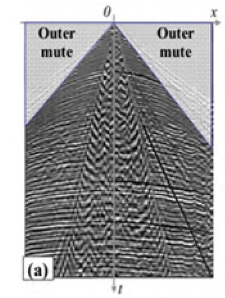
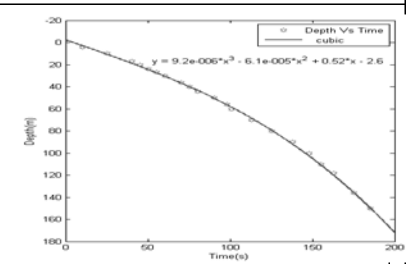
2.4	1. Define white noise versus colored noise, and give several examples for each type of noise. Why is it usually more difficult to suppress colored noise than white noise?	White noise is random energy containing similar amplitudes in all frequencies of the data bandwidth but with random phases, such as the events before the first arrivals in Figure 2.14a. Colored noise has certain regular behaviors that may be similar to that of the seismic signal, such as the multiples in Figure 2.17a which are removed in Figure 2.17b. Usually it is more difficult to suppress colored noise than white noise because colored noise may not be distinguishable from the signal. Though high-frequency random noise can often be suppressed in processing, it is nearly impossible to be completely eliminated.
	2. Discuss the meanings of signals and noise in Figures 2.14a and 2.15a.	Both of these are onshore common shot gathers containing reflections, first arrival waves, surface waves, side scattering waves and other noise. The definitions of signal and noise depend on the scientific and business objectives. For instance, in most exploration seismologic studies, only the primary reflections are taken as signal, then all the remaining events become noise. In most surface-wave studies, the reflection waves may be regarded as noise. When we have limited data but sufficient time, we shall always try to utilize as many usable types of waves as possible.  
	3. Find a couple of examples in the literature on noise suppression in seismic data processing using the τ–p transform.	**Message of No STANDARD SOLUTION:** There are many published studies on this subject.
2.5	1. Discuss the advantages and limitations of using the concept of statics to correct for the near-surface effect on seismic data.	In field applications, simple but practical approaches are often more useful than complicated theories. The model of statics correction for the near-surface effect on seismic data (Figure 2.19) is a good example. The advantages include its simplicity and effectiveness in many cases. The limitations of this approach include its arbitrariness and lack of rigorousness, and the resultant data are no longer surface-consistent.
	2. The sand dune curve shown in Figure 2.20b is a depth versus traveltime plot that can be obtained from an uphole or a check shot survey. Derive a 1D velocity function based on the depth versus traveltime plot in Figure 2.20b.	The slope of the depth versus time curve in Figure 2.20b is the 1D velocity function v(z). In case of rough uphole data, we can first fit the data for the depth function z(t) as a polynomial of traveltime t, and then obtain v(z) = d[z(t)]/dt. The figure shown here is an example of fitting uphole data (circles) for the z(t) function. 

	3. Search the literature to write a short description for: (1) refraction statics; (2) reflection statics; and (3) trim statics. Which method is the most effective?	Refraction statics are static time corrections for reflection data to compensate for the effect of near-surface weathering zone at the shot and receiver locations. The corrections are estimated based on first arrivals traversing through the near surface. They represent the long-wavelength components of the near-surface statics. Reflection statics are static time corrections based on traveltimes of shallow reflections traversing through the near-surface weathering zone. They represent the short-wavelength components of the near-surface statics. Trim statics are small (less than 1/3 of the main period) static time corrections estimated based on aligning reflections in neighboring traces. Tram statics method is usually the most effective among the three, though it is less physical than the other two static corrections.