GeoCom

Statistical Seismic Balancing

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January 1998

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Introduction

This paper will describe briefly the method used by GeoCom Services Australia to match the time, phase and amplitude of different vintages of 2d seismic data to facilitate more accurate workstation interpretations. Detail will not be given as to routines used; rather an overview of the decision-making philosophy will be given. The inadequacies of non-statistical methods will also be discussed. The appendix contains full-page versions of all figures.

Criteria for Shifting 2d Data

When balancing seismic data, certain constraints must be remembered:

1. By definition, 2d data must mistie. Figure 1 shows a histogram of the phase mistie between lines of the same seismic survey. Although all the lines have been recorded and processed using the same parameters, apparent phase differences of up to 90° are common. The data used in this histogram was all modern offshore surveys. The shape exhibited represents a Gaussian distribution and is the optimum output we should aim for when matching lines of different vintages. It is symmetric as all line intersections are used, i.e. LINE-A intersecting LINE-B as well as LINE-B with LINE-A.
2. We are trying to remove effects caused by differing recording and processing parameters; not those introduced by raypath differences.
3. For 2d data to tie, it must be perfectly flat in both time and depth for some distance around the intersection. This is seldom the case, especially at well locations.
4. Lines within the same vintage should never have different shifts applied.

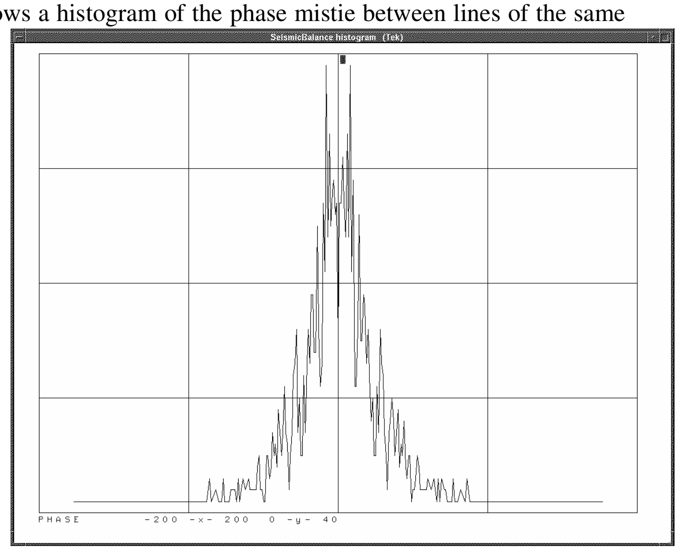

Figure 1 Apparent phase mistie inherent within 2d seismic data

The Non-Statistical Approach

Most current methodologies rely on choosing certain discrete points to analyse mistie values. These points are typically key seismic lines and well locations. The results from these points are then applied to the whole survey. This method fails to take into account all but the last constraint listed above.

A workflow would be something like:

1. Using analytic methods, tie a key regional line to a well or series of wells, this line then becomes the base line.
2. For each vintage tie a key line from that vintage to the base line. If the vintage does not intersect the base line, then tie to another line that has been balanced already.
3. Progress until all vintages are tied.

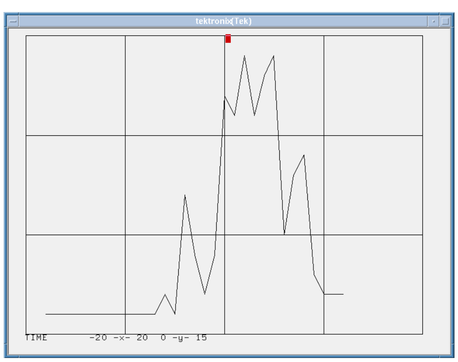

Figure 2a Time Histogram after non-statistical balancing

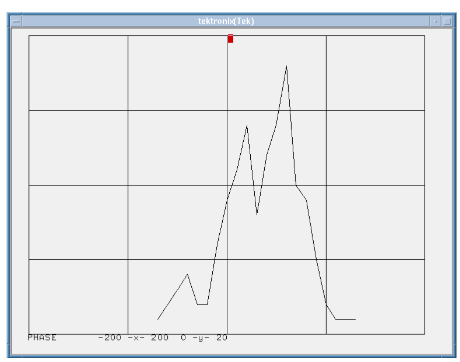

Figure 2b Phase histogram after non-statistical balancing

Figures 2a and 2b were generated from data supplied by a recognised processing contractor. These figures clearly show one of the main dangers of using this method. They give the residual mistie in time and phase after balancing two modern vintages based on a single intersection. There is an obvious 3ms/45° residual mistie.

Using this method, errors compound as you move from vintage to vintage. Based on Figures 1 and 2 we can assume a phase error of ±45º and time error of 4ms at each analysis point, this uncertainty will grow to ±135º and 12ms by the time you get to any vintage not intersecting the base line.

By using a single line as the base, there is limited scope in the choice of target line locations. This means that intersections near faults or geological dip

The Statistical Approach

Rather than use discrete points to determine shift values, the data is loaded to a workstation which then allows us to analyse many intersections. The workflow is:

1. Load all data to SeisWorks in 32 bit F.P. format. SeisWorks is used as it can output analyses at every intersection rather than a subset. This software is used only to calculate the raw mistie in time, phase and amplitude at each intersection, none of the analysis is done in the package.
2. Choose a base vintage to which everything else will be matched.
3. Find the vintage that "best overlaps" the base vintage. ***This decision is key,*** the order in which vintages are matched will significantly affect the final result. This is unlike the non-statistical method, which is commutative (order independent). Factors affecting the choice of vintage include:
    - Number of intersections with base
    - Quality of seismic
    - percent of vintage lines that intersect base
    - increase in percent of usable lines if other vintages are balanced first

   Vintages that contain only a few lines are left to the end to build a large statistical base.
4. Produce a listing of the observed time, phase and amplitude mistie for every intersection of the base vintage with the target vintage.

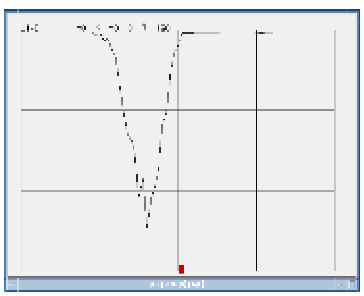

Figure 3a Time mistie histogram

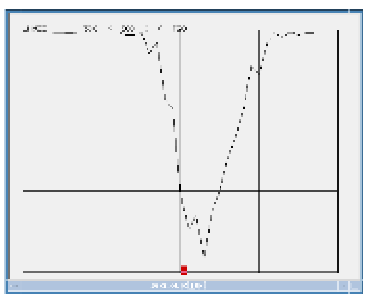

Figure 3b Phase mistie histogram

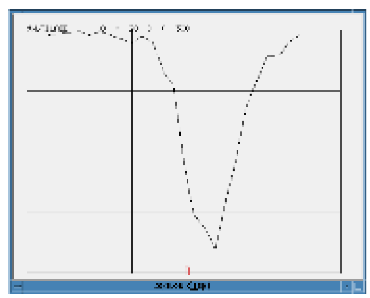

Figure 3c Amplitude mistie histogram

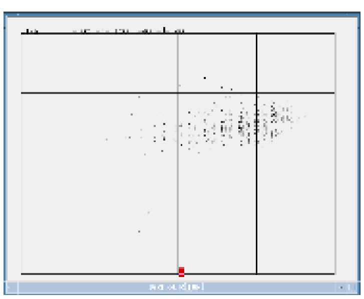

Figure 4a Time mistie crossplot

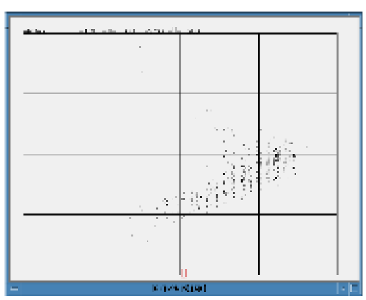

Figure 4b Phase mistie crossplot

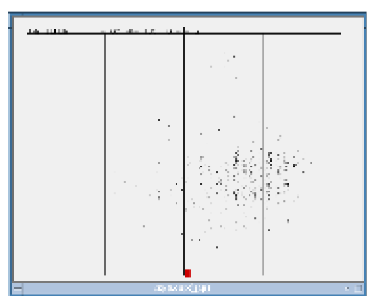

Figure 4c Amplitude mistie crossplot

5. Various graphical and statistical methods are then used to determine the optimum shift in each of the three domains. Histograms (figures 3a, 3b and 3c) and crossplots (figures 4a, 4b and 4c) are generated and the mean, mode amd median are also calculated as a cross check.

   In this example the following mistie would be derived in the three domains

   t = -9ms
   Ø = 30º
   y = 1.8

6. The target vintage is then shifted and these lines are then incorporated into the base set.
7. Return to step 3 to determine the next vintage and iterate until all data is matched.

Using this method, when moving from a base survey of 100 lines to a target survey of 200 lines, typically we are able to use (say) 500 intersections rather than only one as in the standard method. Even careful choice of the one location would not guarantee a good result.
Errors do not compound using this method as all previously balanced data is considered as “base” and is used in subsequent iterations.
The X-axis of the crossplots is cross-correlation coefficient, with a better quality intersection indicated by a larger X value.
These plots are also useful for identifying problems in the target vintage. Secondary “clouds” on the crossplots or peaks on the histograms can indicate sub-vintages with differing processing parameters. It is impractical using a non-statistical method to isolate such problems.

Results

Figures 5(a&b) and 6(a&b) show the combined results of several large balancing jobs. In total there are over 50000 intersections representing 40 different vintages and 35000km of seismic data.

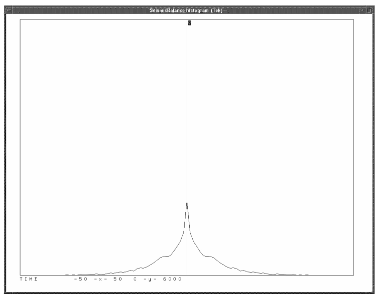

Figure 5a Time histogram prior to balancing

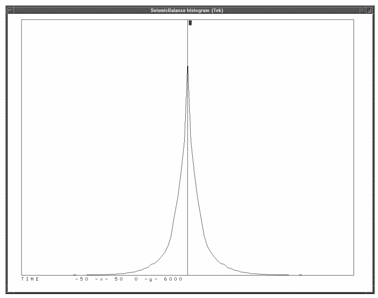

Figure 5b Time histogram after balancing

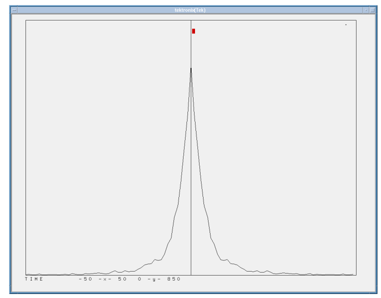

Figure 5c Time histogram after non-statistical balancing

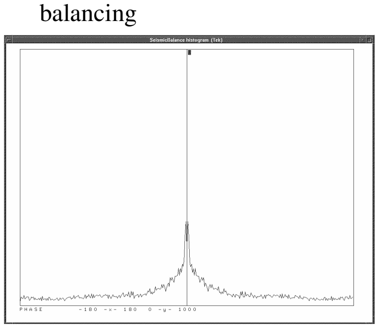

Figure 6a Phase histogram prior to balancing

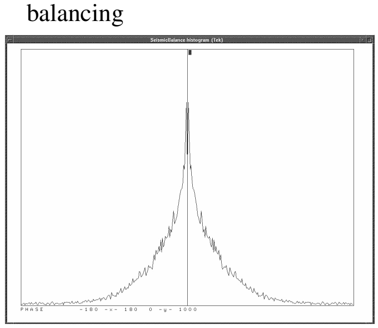

Figure 6b Phase histogram after balancing

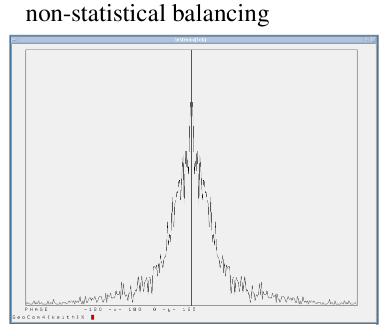

Figure 6c Phase histogram after non-statistical balancing

It must be remembered that we are not trying to remove all misties, rather we are trying to build a perfect Gaussian spread of values. Figures 5c and 6c represent the results of a project about half this size using a non-statistical method. Although the general shape is similar to the statistical results, two key features are worth noting:

1. The width of the histogram at about 50% of the peak frequency is 60% larger. This means that there are 60% more misties of about 8ms and 30°.
2. There is more structure in the histograms from the non-statistical method. This indicates descrete mistie values that are more common, for example 12ms.

Results of balancing exercises are often shown by a judiciously chosen zig-zag line. Invariably they contain the same intersections that were used in the analysis, and therefore would always look good. The true test of a balancing exercise is to look at all intersections and this can only be done realistically in plots like figures 5 and 6.

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