Seismic DNA – A novel visually guided search method using non-local search and multi-attribute data sets
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Summary
We present a new approach to extract features from seismic data using a non-local and multi-attribute search method. By transforming seismic reflection data and attributes derived from seismic data into characters we can search for complex features in the seismic data volumes using a text-based search technology. The method presented here allows for feature patterns with a varying vertical extent, varying attribute values and a varying number of sub-features in the feature signature. We describe the method and give two examples of how it can be used. The first one shows how the number of sub-features can vary in a feature. The second one shows how we can combine different attributes in one search.

Introduction
We propose in this paper a new approach to extract features from seismic data using a non-local multi-attribute search method. Automated extraction of subsurface features is of great help to seismic interpreters. The features could be surfaces, faults or volumes. Examples of such methods are automated horizon extraction Borgos et al. (2003) and automated fault extraction Pedersen et al (2002). Even though these tools become better and faster there are situations where the information a geologist uses is non-local – a certain feature cannot be selected based on one (or more) attributes at a certain seismic reflector. To overcome these difficulties methods like sequence classification, Borgos (2006) and textures identification Carrillat (2002) have been used for non-local feature identification. In the case of features only detectable through the combination of different attributes volume co-rendering and sculpting can be used with success. (See for example Chaves 2011)

One further complication that makes the extraction of subsurface features more challenging is the variability of the sought for features. This variability could not only be restricted to the changes in numerical values (i.e. seismic amplitude along a surface), but also the number of surfaces in a sedimentary package. One example of this is shown in Figure 1.

The Seismic DNA method
In the core of our method is the ability to search through the data as if the data was text. By properly translating and ordering the data we are able to create search expressions that include relative positions and distances between different parts of the features we are searching for.

Figure 1: Seismic line showing two selected surfaces as white and blue points (lower panel). The two point sets have been extracted using one Seismic DNA signature allowing for amplitude variations along the surfaces as seen in the upper panel. The signature also allows for the existence of additional reflection events between the two surfaces. These events are marked with crosses in the upper panel.

The search expressions are similar to regular expressions used in text searching. (Wikipedia 2011) Below we first describe the different steps in the workflow before we show how we can build up the different building blocks into feature signatures. We conclude by showing two example of the use of the method described below.

The first step in the workflow is to translate the continuous data into characters. This is done by assigning each character to a unique range of data values, for example
Seismic DNA

{a; b; c} → {[-∞, -0.5>; [-0.5, 0.5> ; [0.5,∞>}.        (1)

The number of characters sets the resolution of the search. The value ranges do not need to be of equal size or evenly distributed over the valid range of values. The value ranges should be adjusted to the problem at hand.

The second step is to create a regular expression which describes the feature we are searching for. A simple regular expression is [ab]{1,5}. Here the letters in the square brackets say which range of values we except. If we use the same translation as the one describe in equation (1) the allowed range is from -∞ to 0.5 covering the two character classes ‘a’ and ‘b’. The numbers in the curly brackets say how many subsequent repetitions of values in this range we will accept as a valid match. The regular expression search also allows for zero repetitions. This means zero repetitions are also a valid match. Using this feature we can create more complex regular expressions where some sub-features may or may not be present in a valid match.

To create a usable system for interpreters we have encapsulated the translation and the regular expression into tangible objects in software for seismic interpretation. All information needed for translation of numerical values into character classes is encapsulated in a Translator object. The regular expression is encapsulated in a Gene object. Together these two objects can be combined into a Signature. This signature then describes how to translate data and search in this dataset. If a feature can only be described using several attributes it is possible to combine different pairs of translator objects and gene objects into the same signature. An example of such a signature is given in Figure 2. By storing the search in this way we are storing not only data as in the translation boundaries, but also knowledge. A signature contains the information the interpreter used to describe the feature of interest. Once electronically stored in the signature it can be used again on the same dataset or on new datasets. It can also evolve based on the available data by adding or removing translator – gene pairs.

Figure 2: Structure of a Seismic DNA signature. Each translator – gene pair is applied to one of the input data in a combined search. The search result is presented as a geometric primitive. In this case a pointset.

Seismic DNA graphical user interface

The Seismic DNA technology as described in the previous section is not straight forward to apply. An interpreter would need to translate the data and also be skilled in the use of regular expression like search patterns. To enable an interpreter to use the Seismic DNA technology without the need of deep knowledge of the underlying technology we have developed software which let the interpreter do the translation and the design of the search expression using a graphical user interface to interact with the seismic data.

Two actions are required by the interpreter. The first on is to select a translator for translating the data into character classes. In the user interface the character classes are represented by colors and the selection of the translator is done by using a customized discrete color bar which can be edited with real-time updating of the seismic display. This graphical translation is shown in Figure 3 and Figure 4.

Once the translator properly displays the features of interest the interpreter selects the seismic events that are part of the feature and a visual representation of the search expression or gene is created. This visual representation contains both the spatial (length) and data (character class) information of the search expression. In addition a pointset displays the result of the search. When a search expression is selected the search result can be fine tune by changing both the translator and the gene. All changes on both the translator and the gene are reflected in the seismic data and the pointset representing the search result. This allows the interpreter to get instant feedback on the quality of the translator and the search expression.

An example of translated seismic data, a gene and the search result is given in Figure 5. The seismic inline displayed in the figure is shown with the translated colors in the upper panel and with the continuous seismic amplitude in the lower panel. The visual representation of the gene is shown at the right edge of the figure. Here the
colors in the gene correspond to the colors on the translated seismic inline or the translated characters. The first column in the gene corresponds to the minimum length of the current color of the gene. The second column corresponds to the maximum length of the current color of the gene. Thus this visual representation displays all the information stored in the regular expression format given in the last section, but here it can be directly compared to the geological features it represents in the seismic data. The result of the search done by using the translator and the gene from Figure 5 is shown in the figure as three different point sets. The point sets correspond to the blue and red elements of the gene.

**Reflector pair with internal events**

This example shows how we can create a signature which matches a pair of reflectors even though there are internal events between the two reflectors at some positions. By creating a simple signature we can track the two surfaces of interest. This simple signature does however run into problem when internal events, for example channels appear between the top and base surfaces as seen in the upper panels of Figure 6. Further investigation of the seismic showed that the missing parts of the surfaces had the same amplitude signature as the detected part. The only difference was the existence of internal events at these positions. We expanded the signature to allow for up to three extra internal events to appear or disappear between the top and base surface. The search with this new signature extracted both surfaces regardless of whether the internal events where present or not as seen in the lower panels in Figure 6.

**Horizons intersected by faults**

We want to extract a surface from a seismic cube with the additional condition that the surface should be discontinuous where the surface is intersected by faults. To achieve this we performed a search on the seismic amplitude and on a chaos based discontinuity attribute as shown in the left panel of Figure 7. We create a combined signature as sketched in Figure 2 and perform the search on the data. The result of the search is displayed in the right panel of Figure 7. Here we see the discontinuities in the surface. If we had applied a traditional auto-tracker to extract this surface we could not have gotten this result. The reason for this is that the seismic amplitude variations are larger inside one continuous segment of the surface than the change in seismic amplitude caused by the faults. This search is of nature multipoint and multiattribute since it searches for a non-local feature describe by two input attributes.

**Conclusions**

We present a new method for searching in seismic data using a regular expression based search technology. The flexibility in the search technology allows us to search for features which have a varying vertical extent and varying attribute values along the feature. It also allows us to perform searches using several attributes at the same time. We believe our method is a useful tool for capturing more complex features in seismic data. The graphical user interfaces described above can be used with more than one input attribute as was used in the second example.

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Figure 6: Search results for the a pair of strong reflector as 3D (left) and 2D (right) pointsets. The upper row shows the result without internal events as 3D and 2D pointsets. The lower row shows the result with internal events. The black horizontal lines are the position of the seismic sections.

Figure 7: Discontinuity attribute in blue overlaid on the seismic (left), and the search result for the combined search displayed as a pointset in 3D (right). Notice the discontinuous surfaces marked by the arrows.
EDITED REFERENCES

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REFERENCES


