The Study of OpenDtect Seismic Data Interpretation and Visualization Package in Relation to Seismic Interpretation and Visualization Models

Izzatdin Abdul Aziz†, Jafreezal Jaafar †, Abdul Rehman Gilal ††

† Computer and Information Sciences Department, Universiti Teknologi PETRONAS, Malaysia
†† Department of Computer Science, Sukkur IBA University, Sukkur, Pakistan

Abstract:
Seismic interpretation software acts as a tool to assist geophysicists in making accurate geological predictions and decisions. Many geophysicists believe that the reliability of seismic interpretation software and its compatibility with other seismic data processing packages is the key instrument to an accurate well prediction. In this report we study the OpenDtect seismic visualization and interpretation tool in relation to seismic reflection methods. Representing seismic data in a 3 dimensional forms (3D), discern more seismic attributes or information to be visible from a seismic dataset. In a geological mapping operation to collect seismic data, reflecting signal tend to diffract and bend when propagating towards the Earth subsurface having various densities. In a complex geological structure, the Earth subsurface posed a major challenge in understanding seismic signal reflections. Reflecting signal velocity is an important attribute to the understanding the Earth subsurface thickness and materials. Velocity model is used to match the seismic dataset with its accurate seismic traces obtained from a geological mapping operation. The accuracy of matching velocity value with its corresponding seismic trace allows precise depths estimations of the Earth subsurface structures. Understanding geological structures underneath the earth surface is essential to estimate and predict the existence of hydrocarbon traps.

Key words:
Seismic visualization, open source seismic visualization package, hydrocarbon exploration, geophysical exploration, seismic data interpretation, OpenDtect

1. Introduction

The race to explore and determine hydrocarbon wells is intense. The initial geological exploration process followed by seismic data processing and interpretation; to the actual drilling of an oil and gas well would take up to almost a year [1]. Making an accurate and prompt decision on hydrocarbon well drilling points is vital, but nevertheless without a risk. Due to the highly complex subsurface geological formation, misinterpretation of seismic data may occur. Misinterpretation of seismic data often leads to the drilling at an inaccurate location such as piercing a dry well. Hydrocarbon drilling operation is highly expensive and could reach up to USD 4.5 Million in extreme conditions such as deep water drilling and sub-zero temperature [2]. Therefore one could imagine the impact of an erroneous decision subject to a misinterpretation of a seismic data.

Seismic data interpretation and visualization package is equally important as compared to seismic data processing packages. Output from seismic data processing packages are feed into seismic interpretation and visualization package in order to assist geologist in predicting hydrocarbon traps and reservoirs in the highly complex geological subsurface. The seismic interpretation and visualization packages such as OpenDtect allow geo-expert to identify possible hydrocarbon reservoirs. OpenDtect is an open source seismic data interpretation and visualization package. Computer, as well as geophysics experts contributes actively to the development and enhancement of this package. The active contribution of ideas and seismic models to the package has made it rich of computational functions which represent many reflection seismology models. Due to its comprehensive features, many researchers utilise this tool for various purposes such as seismic attribute extraction [3-4], seismic images conversion, seismic images visualization and interpretation [5].

Seismic, visualization and interpretation models are represented in the forms of modules or extension to the OpenDtect package. Modules are available as open source as well as proprietary. For instance, an advance or customized seismic model such as velocity model building is available for user to download and install as an extension to the OpenDtect package [6].As a seismic interpretation and visualization package, OpenDtect supports output from other seismic data processing software such as Madagascar [7]. Madagascar is a popular open package for processing and manipulating seismic data [8]. OpenDtect supports the Madagascar Reproducibility Sample Format or better known RSF for processing continuous streams of seismic data.

OpenDtect comprises of seismic velocity model in which is discussed in the sections of this report. Section 2 discuss on

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the essential features and functionalities of OpenDtect. Section 3 discusses the 3D pre-stack seismic data analysis model. Section 4 discusses the Velocity Model Building which uses signal travelling time to rectify each signal reflection point in a seismic migration process [9]. Section 5 will discuss on seismic signal migration process to correct the signal reflection points during a geological mapping operation. Section 6 discuss on the OpenDtect capability to support the Madagascar seismic computational functions and function execution. Section 7 concludes our report on the study of OpenDtect in relation to reflection seismology models and we present our future works.

2. OpenDtect Feature and Functionality

The main features of the OpenDtect package are the Horizon Tracking capability, Visualization and Seismic Attributes. It is a graphical user interface or GUI based software supporting three platforms which are Windows releases, Mac OS/X and Linux distributions. We have installed the OpenDtect version 4.4 in a Linux Ubuntu version 10.10 on Universiti Teknologi PETRONAS High Performance Computer cluster which is physically located at the university's High Performance Computing Service Centre. Subsection 2.1 describes the term horizon and explains the Horizon Tracking technique. Subsection 2.2 describes the Seismic Visualization functionality and subsection 2.3 defines seismic attributes.

2.1. Seismic Horizon Tracking

Seismic Horizon signifies as a stratigraphic level or a layer of the Earth subsurface. Horizon in seismic also corresponds to the surface of an Earth medium on a 3D coordinate system of an x, y and z plane [10]. The Earth is made up from many layers, where each layers has a horizontal surface. OpenDtect is capable of constructing a 3 dimensional (3D) image for each of the Earth layer from a processed seismic data. The process of constructing a visual representation of a seismic horizon from seismic shot records is known as Seismic Horizon Tracking.

2.2 Seismic Interpretation and Visualization

The ability to visualize seismic data is important to assist geophysicist in determining the Earth subsurface compositions. Interpreting the Earth structures and compositions such rock sediments; granite, salt, water and porosity is essential to determine possible hydrocarbon traps. Hydrocarbon builds up often near permeable medium such as salt and sand. The porous attributes of a medium such as salt and sand allows hydrocarbon fluids to seep up to the surface from intense upwards Earth mantle pressure. The Hydrocarbon fluids movement often halt when obstructed by a solid Earth layer such as rock. The accumulated hydrocarbon fluid known as the hydrocarbon reservoir is commonly trapped in a predictable chamber-like Earth structure.

Recent graphic technology made possible the construction of a 3D seismic image from processed data. The 3D image subsist in a 3 coordinate system; which is the x-plane; representing horizontal surface; the y-plane; representing the vertical surface and the z-plane; which represents the depth as depicted in figure 1.

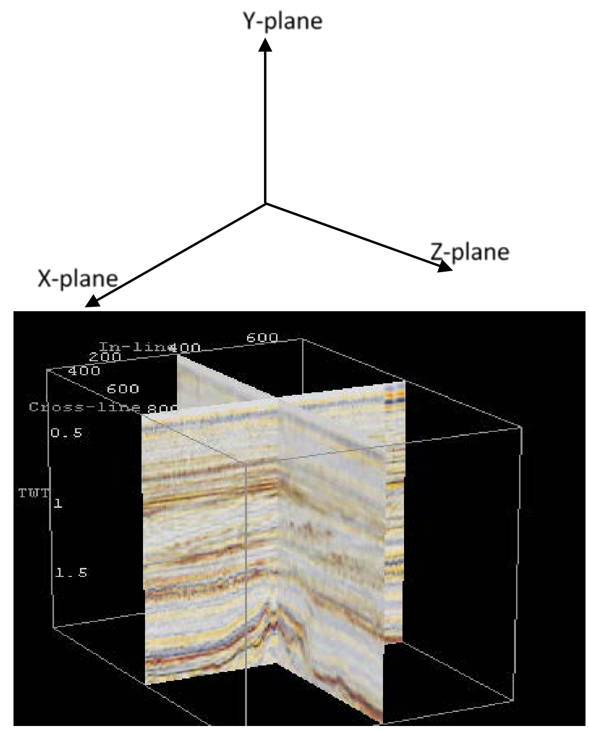

Fig. 1 The x, y and z plane which represents the horizontal, vertical and depth surface respectively

Figure 1 depicts a 3D visualized seismic data which exist in a 3D coordinate system. The geological structure and the Earth substructure are apparent. The success of interpreting seismic data set often lies on the richness of information manifests on a visualized data. Enhance graphic properties such as rendering; colour intensities and high dimensional representations are able to enhance the subtle lithology information or attribute that is originally exist in a seismic dataset.

2.3 Seismic Attribute

Many individuals and organization have been describing what Seismic attribute is [12-14]. From our reading, we discover that seismic attributes are the quality ascribed in a particular seismic data set. Seismic attributes are defined as all the information obtained from seismic data, either by direct measurements or by logical or experience based reasoning [15]. Seismic attributes are essentially derivatives of the basic seismic measurements i.e. time, amplitude, frequency and attenuation which also form the basis of their classification. It was also defined; as a measurement based on seismic data such as envelope, instantaneous phase, instantaneous frequency, polarity, dip and dip azimuth [16]. According to [12-14], the classes of seismic attribute can be defined as shown in table 1.

Table 1: Seismic attributes classes and description [12-14].

Attribute	Description
Velocity	Velocity model is used to map with seismic data in order to produce an accurate construction of seismic time image for visualization and interpretation purposes.
Impedance	The Earth layers are made of materials with different impedance level. Signal often diffracted and bended when propagating through materials with different impedance level. Signal reflections are rectified when supplied with accurate impedance reading. The correction of signal produced an accurate visual representation of a seismic data.
Sediment	The depositions of sediments underneath the Earth surface are closely linked to the physical representation of the Earth strata [1]. The ability to enhance delicate earth material enriches the value of a seismic data.
Surfaces	Horizontal; vertical and depth surface representation reduces the complexity and orientation in understanding a particular seismic data set. The availability to map seismic data in a higher dimensional surface allows better depiction when analysis and interpretation is performed.
Seismic Traces	Seismic traces are representation of signal reflection time often generated and measured in time domain allows prediction of distance, length and thickness of the Earth subsurface. The accuracy of distance and thickness of an earth layer will assist experts in estimating the volume of a structure that lies underneath the Earth surface.
Porosity And Permeability	Porous Earth medium such as sand and salt allows liquid such as water, gas and oil to seep through pockets of air and migrate upwards due to intense Earth mantle pressure from underneath. The ability to identify porous medium allows expert to predict the existence of hydrocarbon build up in a particular basin.

A broader characterization of seismic attribute according to [17], are all measured properties obtained in a seismic data. The properties include geometrical information of signal reflections; angles and seismic trace stacks variations [8]. Section 3 discusses in how seismic traces and seismic stacks can be depicted in a higher dimensional visual representation in OpenDtect.

[1] Strata refer to the layers of media lies underneath the Earth surface.

3 Pre-stack 3D Seismic Data

In [8], we have discussed how seismic traces are recorded and stacked. OpenDtect provides the capability to represent seismic data stacks in a 3 dimensional form. In subsection 3.1 we discuss how 3D seismic data is obtain. Subsection 3.2 discusses the elements of 3D seismic data image visualization.

3.1 Acquiring 3D Seismic Data

The construction of a 3D seismic data instigate during the geological mapping process. According to [9], seismic data are made of signal reflection points captured by receivers during a geological mapping process. The number of dimension of the seismic data depends on the layout deployment of the signal receivers better known as geophones or hydrophones [18]. The 3D geological mapping operation uses at least 2 signal sources to produce artificial acoustic signal. Signals produced from the source propagate downwards reflecting on the Earth subsurface having different impedance level [9]. Figure 2 shows the layout deployment of receivers in a marine based geological mapping operation to acquire 3 dimensional seismic data.

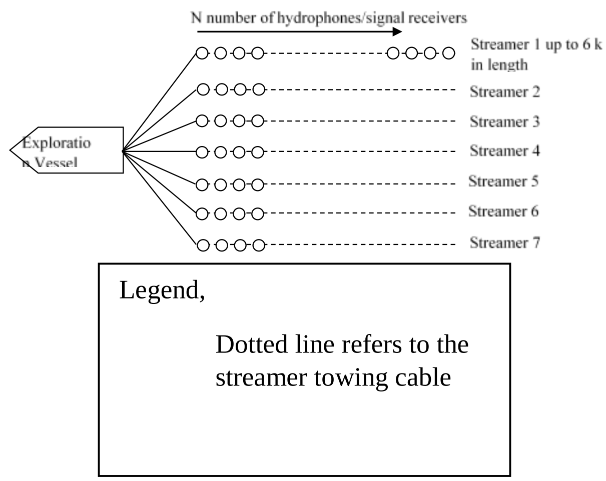

Fig. 2 Signal receiver deployment layout viewed from top during a marine geological mapping operation to acquire 3D seismic data

In figure 2, during a marine based geological operation, a single exploration vessel is able to tow more than 7 streamers of hydrophones or receivers in a parallel layout. Each streamer reaches up to 6000 meters in length and consists up to 480 receivers. The number of receivers depends on the distance interval set between each receivers. For instance, if the receivers are set at an interval of 12.5 apart from each other over the 6000 meters stretch, a total of 480 receivers can be towed in one streamer. If a vessel tows up to 7 streamers, this means that a total of 3360 receivers are available to record incoming signal reflections from multiple directions. Simultaneous signal readings gathered from the receivers towed by the streamers will construct a higher dimensional seismic data representation [1]. Signal reflections captured by the receivers from multiple angles and directions allow the construction of a seismic data encompasses different orientation and dimensions. Data are captured and stored in tape drives. Up to 1000 tapes can be used to store a 3D seismic data for a 600 km2 of a geologically mapped area [1]. Section 3.2 discusses the multiple dimensions of seismic data having manifold elements such as inline, crossline and time slice.

3.2 Inline, Crossline and Time Slice

The representation of seismic data in 3D, gives geological interpreter the ability to orientate the data from many angles. A 3D seismic data is often visualized as a cube. The 3D cube is build up from 3 elements, the inline section, crossline section and time slice section.

3.2.1Inline

Inline correspond to the Earth subsurface lines often distinguish in a seismic time image . In a displayed seismic data, inline is a visual representation of the Earth subsurface in a 2D form [13]. In a geological mapping operation for hydrocarbon exploration, inline refers to the seismic line within a 3D mapping which is parallel to the direction in which the data were acquired. In a marine based mapping, the inline direction is that in which the mapping vessel tows the streamers [13]. Figure 3 shows an inline for a simulated seismic data in OpenDtect.

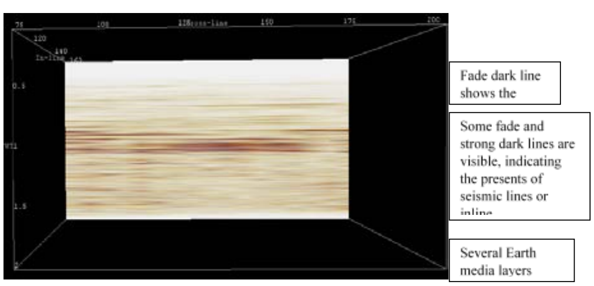

Fig. 3 Blurred and strong dark lines indicate the Earth subsurface or inline

Figure 3 is a 2D representation of the Earth subsurface generated using OpenDtect. This 2D visual representation is called the inline. Inline is the 2D flat representation of Earth media layers. The mist upper visible line in figure 3 is the Earth surface. The lines underneath the surface line are the Earth subsurface or inline. In the center of figure 3 shows a darker concentration of lines. This indicates numerous interception of Earth media layers are presents at that particular region.

3.2.2 Crossline and Time Slice

The crossline section is the seismic line that is perpendicular to the inline section. Figure 4 depict the correlation between inline; crossline and time slice in a 3D seismic data geological mapping operation.

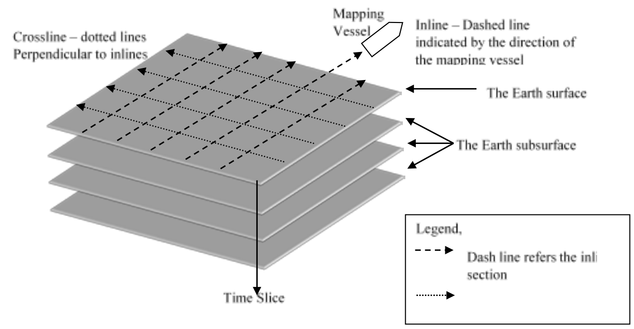

Figure 4: Blurred and strong dark lines indicate the Earth subsurface or inline

In figure 4, the geological mapping vessel's direction indicates the inline, while the lines perpendicular to the inline are known as the crossline. The Earth subsurface is distinguished by the grey flat layers stacking on top of each other. The signal travelling time between each Earth subsurface indicates the time slice section.

4 Velocity Model Building

In [9], we have detailed out the underlying concept of signal travelling time in relation to the variable velocity reading during a geological mapping operating. Signals propagated towards the Earth subsurface passes through various materials; structures and densities. Signal velocity changes as it passes through the Earth materials with different densities. There is a need to be vigilant when dealing with velocity due to the fact that several types of velocity exist when performing seismic data processing. Subsection 4.1 explains the various types of velocities. Subsection 4.2 discusses the matching of velocity with seismic shot records. This matching operation is popularly known as 'velocity picking'.

4.1 Various Types of Velocities

According to [9], velocity in geophysics is defined as the rate of a wave or signal that travels through medium; it is commonly symbolized by 'v'. In seismic data processing, velocity value that is obtained when analyzing seismic shot records is called stacking velocity. In [8], we have explained

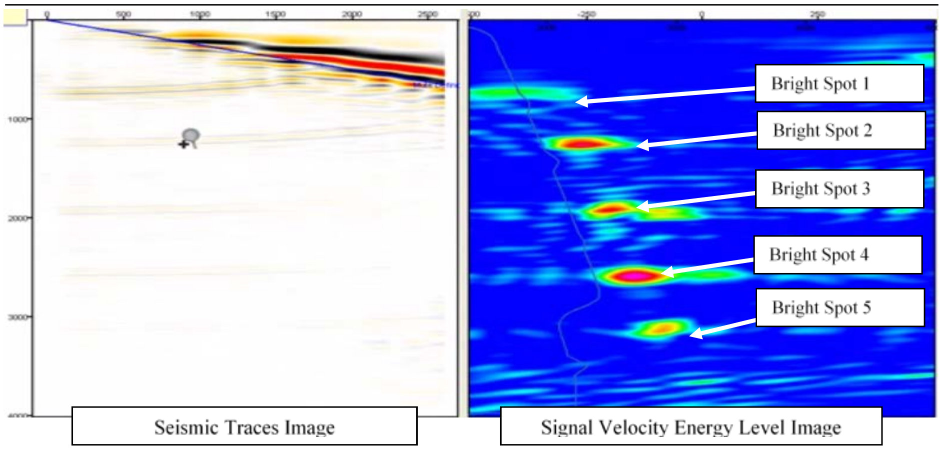

Fig. 5 Image on the left indicate the seismic traces where by image on the right is the signal energy level. Bright spot shows the high energy values [7].

the stacking of shot records or seismic traces. During a geological mapping operation, each seismic trace is recorded in the form of signal travelling time. The constant movement of the mapping vessel and its receivers as previously shown in figure 2, result in each seismic trace to be stacked on top of each other when the signals were recorded [9], hence the name seismic stack.

The stacking velocity is approximately the root-mean-squared velocity or known as RMS velocity. The RMS velocity is an estimated or crude velocity value of the seismic data or traces. In order to verify the correct velocity value for each seismic trace, a trial and error matching operation between the velocity value and each seismic trace needs to be done. This trial and error process is called velocity picking [1].

4.2 Velocity Picking

During a geological mapping operation, signals are projected towards the earth subsurface and reflect upwards. The reflected signals travelling time are recorded at the Earth surface. The signal travelling time recordings tells the areal surveyed depth as a function of time. Thus, the Earth subsurface depth is often measured in the time domain.

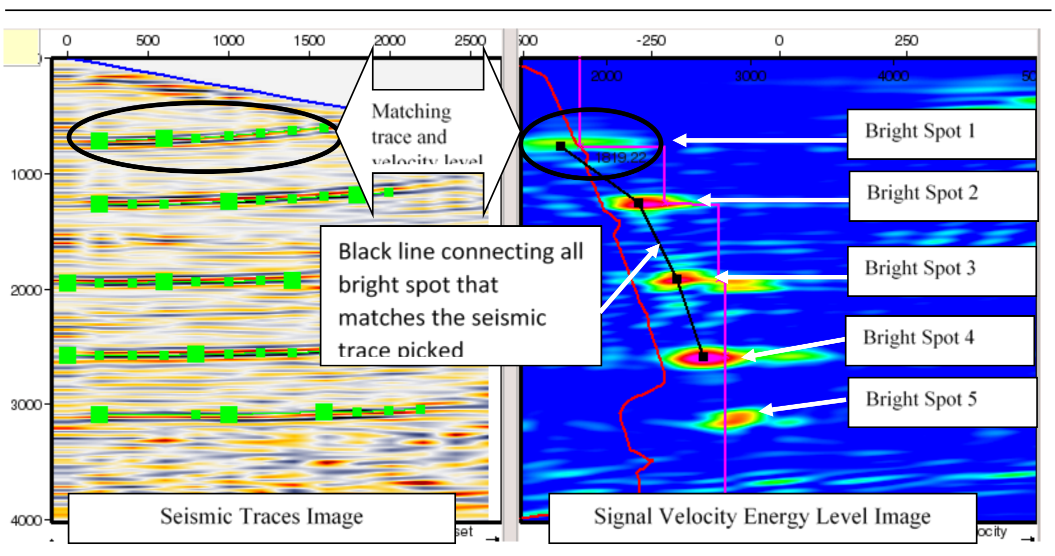

Fig. 6 Image on the left indicate the seismic traces where by image on the right is the signal energy level. Bright spot shows the high energy values [7]

Velocity picking is defined as the picking of velocity and time pairs based on the coherency between multiple seismic signals [19]. Reflected signal recordings consist of high and low velocity energy readings. The first step in velocity peaking is to identify the high energy reading or peaks. Peak energy of a signal is often represented by bright spots in a visualized 2D or 3D seismic dataset. Figure 5 shows the high velocity energy signal reading with bright spot generated in OpenDtect presented on the right hand-side image, and the seismic traces on the left hand-side image.

In figure 5, the seismic traces and its signal energy value is represented side by side. However, the seismic traces do not correspond exactly to the energy level of the seismic traces. The seismic traces which are signal travelling time recording and signal velocity energy value needs to be match. To match the seismic traces and its signal velocity energy value, velocity with high energy value is identified. The high energy value can be identified by the bright spots in the energy level image on the right.

The subsequent step is to match the seismic traces present on the seismic trace image with its corresponding signal velocity energy level. The semblance of the signal velocity energy value image will act as a guide to pick the matching seismic trace. In figure 6, seismic traces were matched with the signal velocity energy according to our heuristics and bright spot semblance in the velocity energy image. There is no exact method to accurately pick the velocity energy value to match the seismic traces thus far [1][20].

Figure 6 depicts a screen shot of the same two images previously shown in figure 5. However in figure 6 we have performed the velocity picking to match the seismic traces and velocity signal energy level for the first bright spot. The dark circles in the seismic trace image on the left hand-side and velocity energy image on right hand-side shows the matching of both seismic traces and its corresponding velocity energy value. The velocity picking process is subsequently repeated for bright spots 2, 3, 4 and 5.

The final stage of the velocity picking process is to draw a line connecting every bright spots correspond to the seismic traces that we have matched, as shown in figure 6. The whole process of picking the velocity energy value and matching them with the seismic traces indicate the velocity model that we have built when dealing with other seismic traces within the same seismic dataset. Therefore any future analysis that we intend to perform on the same seismic dataset will use this velocity model.

To validate the correct matching between the picked velocity energy value and the seismic trace, we shall have to perform the Normal Moveout or NMO process [8]. NMO is the process of eliminating noise effect that manifest in the Common Depth Point gathers or CDP gathers.

During a geological mapping operation, the movement of the exploration vessel will result in the overlapping of signal reflection time records for a common reflection point. The overlapping of signal reflection point and the constant movement of the signal receivers when plotted in a graph often result in a hyperbolic pattern taking shape [8]. The correctness of a velocity model that we have just built can be validated during the NMO process.

During the NMO process, the velocity model is applied on the CDP gathers. If a horizontal stacking pattern is obtained, then the velocity model is correct. However, if the CDP gathers still shows a hyperbolic stacking pattern, then the velocity model needs to be rebuilt. The process of NMO and CDP gathers were previously detailed out in [8].

Velocity picking is important to map the correct velocity energy value for each seismic trace. Having the correct

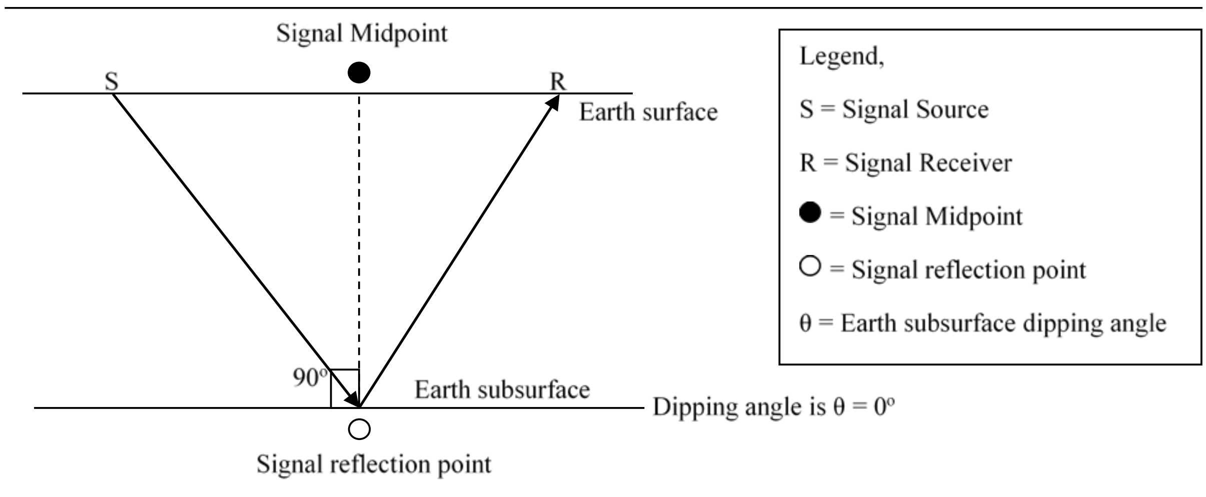

Fig. 7 Figure shows an ideal scenario of signal reflection point. Notice the 90o reflection angle and 0o Earth subsurface dipping angle

velocity value of seismic traces or signal reflection time will allow geophysicists to determine the temporal thickness and depth of the Earth subsurface. In section 5 we discuss the capability of OpenDtect to support Madagascar computational methods and processing. Using the velocity model built, we perform a migration [9] process on a seismic dataset which has previously undergone the NMO process.

5 Signal Migration Process

In a geological mapping operation, acoustic signals are propagated downwards passing through various layers and material underneath the Earth surface. Reflecting signals tend to diffract and bend due to the fact that each Earth layers possessed different densities and thickness. The migration process is a method of geometrically correcting signal reflection point into its true reflection point value. Migration process was previously defined and discussed in [9]. In subsection 5.1, we discuss the signal reflection in an ideal case of geological mapping operation. In subsection 5.2, we elaborate further the signal reflection scenario to include the migration process in a complex geological structure.

5.1 Seismic Signal Reflection

Seismic signal is used to map an area of highly complex geological structure. In an ideal scenario, signal reflects at a flat horizontal surface as shown in Figure 7.

Figure 7, shows an ideal case of signal reflection point. Signal propagating from source at the Earth surface reflects at an angle of 90o at the Earth subsurface before collected at the receivers. In this ideal case, the Earth subsurface has no dip or slope. The slope or dipping angle for the Earth subsurface is 0o. Therefore at 90o signal reflection angle and 0o dipping angle, the signal reflection point possessed the same midpoint reading. In this ideal case of signal reflection, the migration process is unnecessary due to the fact that there is no need of correcting the signal reflection point to match the signal midpoint reading. However, in a real geological mapping scenario, the signal reflects at a more complex geological structure.

5.2 Migrated Signal Midpoints

In most cases of geological mapping operation, multiple signals reflect at an Earth subsurface with various dipping angle. Figure 8, illustrates multiple signals reflections at a 30o dipping angle.

In figure 8, 3 signal shots were fired from source towards the Earth subsurface with a dipping or sloping angle of 30o. Signals S1, S2 and S3 were fired and reflect on a dipping subsurface and received by receivers R1, R2 and R3 respectively. It is apparent in this figure that in the case of a dipping Earth subsurface, the midpoints is not exactly above the reflection point. The three dots in figure 8 show the sequence of midpoints for each signal reflection points. The vertical line up of the three dots; white, grey and black are obviously displaced from all three signals the reflection points. The displacement of each signal midpoints reading with its corresponding signal reflection pint is termed as signal migration process.

The migration process is common supported by many seismic data processing packages such as Seismic UNIX and Madagascar. Thus far, OpenDtect however provides a

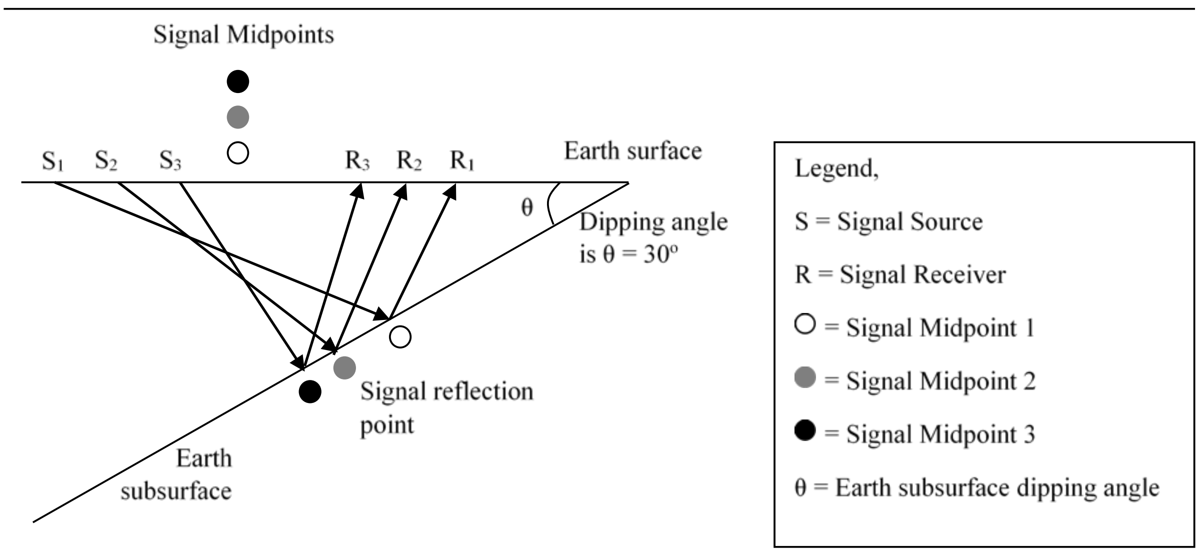

Fig 8 Figure shows an multiple signal reflection point a 30o Earth subsurface dipping angle

utility module to support seismic data processing computational methods from Madagascar. In section 5, we elaborate further how OpenDtect incorporates many Madagascar seismic processing methods in its program which also includes the seismic migration method.

6 OpenDtect Support Madagascar Modules

In this section we merge both Madagascar migration process to execute in OpenDtect. Madagascar is an open seismic data processing package that was previously discussed an elaborated in [8]. It is best to stressed here again that OpenDtect is a seismic visualization package rather a seismic processing package. Therefore seismic data processing can be performed in Madagascar and the output can be supported by OpenDtect. OpenDtect is capable to support all Madagascar seismic computational functions. In subsection 6.1 we discuss the OpenDtect utility that supports Madagascar seismic computational functions. In subsection 6.2, we discuss how the migration process is performed using Madagascar computational functions leveraging on OpenDtect support utility. In subsection 6.3, we discussed the result of the migration process that we performed on Universiti Teknologi PETRONAS (UTP) High Performance Computer (HPC) cluster using a small scale operational seismic dataset.

6.1 OpenDtect-Madagascar Support Utility

In seismic data processing the Migration process is executed after building a velocity model and performing the NMO method. The seismic traces or CDP gathers used for the migration process has undergone noise elimination process. Figure 9 shows a utility in OpenDtect that supports the Madagascar seismic computational functions.

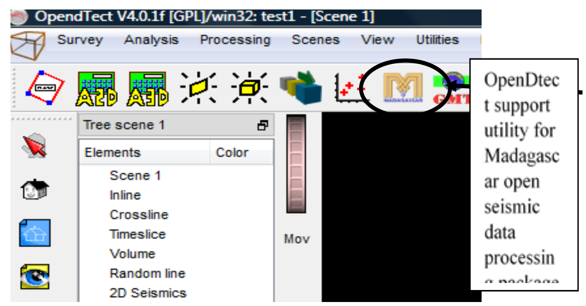

Fig. 9 The icon 'M' noted by the circle indicates the OpenDtect-Madagascar support utility located on the main page of OpenDtect software

In figure 9, the Madagascar support utility is noted by the dark circle located on the panel of OpenDtect main page. The Madagascar open packages needs to be installed and configured prior to using this utility. By pressing the Madagascar utility icon, a pop up window appears as shown in figure 10.

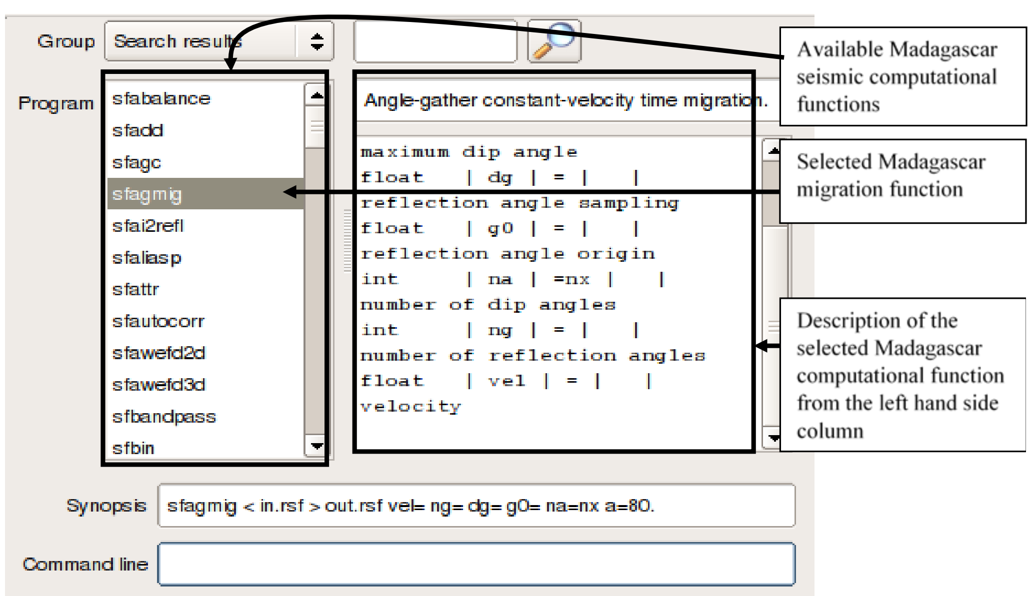

Fig. 10 The scroll down list of available Madagascar computational functions supported by OpenDtect is apparent on the left hand-side column

In figure 10, the available Madagascar seismic computational functions are apparent in the scroll list on the left hand-side of the figure. To date, as many as 300 seismic functions are available. The column in the right hand-side shows the description of the selected Madagascar migration function sfagmig.

6.2 Migration Process using the sfagmig Function

The sfagmig function performs the migration process which takes into consideration multiple signal reflection angles as previously describe in subsection 5.2. The sfagmig performs the migration process for multiple signal reflection on a dipping or sloping Earth subsurface. The sfagmig function requires two input files:

- the data file that contains the CDP gather, and
- a velocity file containing the velocity model that was previously build as describe in subsection 4.2.

The result is stored in a user defined name output file. The following command execution line shows the usage of sfagmig function. The function inputs two files labelled as Seismic_data.rsf and velocity.rsf. Function sfnmo produces one output file labelled migration.out. The sfagmig command execution is as shown below,

```
sfagmig < Seismic_data.rsf >
migration.out vel=velocity.rsf ng=10
dg=60 g0= na=nx a=80
```

The input and output file names are user defined and must not necessarily be named as Seismic_data.rsf or migration.out. The parameters for the sfagmig function and the description of each parameter values are described as follows:

- vel, takes in supplementary input file containing the velocity model value.
- na, refers to the number of dipping angle.
- dg, refers to the reflection angle sampling.
- ng, refers to the number of reflection angles
- g0 is the reflection angle origin from signal source and,
- a, is the maximum dipping angle which is set to default 80o. The sfagmig function assumes the maximum slope or dip must not exceed this value.

The words such as vel; na; dg; ng; g0 and character a are reserved words by the program. The output of this function is the migrated signal midpoint reading according to its signal reflection points.

The sfagmig command execution line was executed on the command line text box provided by the OpenDtect Madagascar seismic function support utility as previously shown in figure 10. Seismic migration process is known to be a computational exhaustive process [1] in seismic data processing. In subsection 6.3, we discussed result of seismic migration process execution on a high performance computer cluster.

6.3 Migration Process Execution

The seismic migration process was sequentially executed on the UTP HPC cluster. The migration process was executed three times prior to recording the average execution time as shown in table 2.

Table 2: Migration program execution times and the average time recording.

Migration Program Execution Trials	Execution Times in Minutes (m)
	CPU (total)
1	7825
2	7357
3	7622
Average	7601

Table 2 shows the time readings for the executions the seismic migration program. The average time for all executions was presented at the last row. The migration program was executed in three consecutive trails. The first trial took 7825 minutes to complete; the second trial is 7357 minutes and the third trial is 7622 minutes. The average elapsed CPU time between invocation and completion of the sfagmig function is 7601 minutes. This includes the two way travel time from the remote terminal to the server and back.

The sfagmig migration program was executed on a single node with 8 cores.

The 7601 minutes of execution time is equivalent to, 7601/60 minutes = 126.7 hours approximately 5 days. The seismic dataset consist of 2.4 million shots records with the overall file size of 240 Gigabytes. In the future, we intend to execute the sfagmig migration program on a larger dataset in a distributed environment using a variable number of compute nodes to measure the performance and speed up pattern of the function execution.

7 Conclusion

In this paper we discussed several key elements of OpenDtect seismic visualization and interpretation package. The 3D pre-stack seismic data visualization feature allows in-depth illustration of seismic data elements such as inline, crossline and time slice. Inline are visual representation of the Earth subsurface in 2D form following the geological mapping operation path. Crossline is a 2D visual representation of lines perpendicular to the inline direction. The time slice is the visual representation of the Earth subsurface flat horizontal plane. The combination of inline, crossline and time slice resembles 3D cube visual of geological structures and subsurface. The 3D visual capability combined with the correct velocity model in OpenDtect uncovers ambiguous seismic details in geological structures.

In hydrocarbon exploration, artificial acoustic signals are used to map an area. Geological mapping is essential to construct a 3D image of structures underneath the Earth surface. Each geologically mapped area holds a distinct signal velocity value. For instance, signal velocity values at the Northern Sea of Europe are different with the signal velocity value at the South China Sea. The discrepancy in signal velocity value is due to the fact that each mapped area consists of unique combination of Earth subsurface materials. An area may contain layers of salt, brine; and hydrocarbon where as another area contains large portion of water, iron and granite layers stacking on top of each other. Building velocity models for an area is crucial to match the seismic dataset obtain from the geological mapping operation. Therefore a velocity model differs from one area to another. OpenDtect allows velocity model building through velocity picking process.

Velocity energy value is obtained during signal reflections through the Earth subsurface. The energy value when represented in an image form is shown as bright and dark spots as shown earlier in figure 5. The semblance image is used as a guide to pick the right velocity value to match the seismic traces. Matching is done by identifying high energy velocity value represented by bright spots with visible stacks of seismic traces. Velocity models are essential in estimating Earth subsurface thickness; composites and depth. Understanding the Earth layers' depth and materials' compositions allows prediction on how deep an oil and gas well needs to be drill; as well as how hard the Earth layer materials are.

OpenDtect supports seismic computational function from other seismic data processing package such as Madagascar. The study of Madagascar open seismic data processing package in relation to seismic reflection models was previously reported in [8]. OpenDtect is equipped with a module to support Madagascar computation function as well as its seismic data format, which is the Regularly Sampled Format or in short, RSF.

We have performed a seismic reflection signal migration process to geometrically correct the signal reflection point using a historical seismic dataset. The dataset is 6 Gbytes in size consisting of 2.4 million seismic traces. The seismic migration program was sequentially executed on UTP HPC cluster. The program was executed on a single compute node with 8 cores. As many as 3 trails of the seismic migration program were executed within the duration of 15 days. The average of the 3 trails was recorded. The average CPU execution time is 7601 minutes which is approximately 126 hours or 5 days.

In the future we intend to perform similar computational exhaustive seismic program such as the time migration program on a distributed environment. Work is on the way to parallelize seismic programs using Message Passing Interface or MPI. We are also working on SCONS to support parallel program executions. SCONS is a software construction tool which uses python programming language and scripts. It is a high level wrapper behaving similar to a makefile in UNIX systems. In the next report we shall elaborate further our work on seismic data processing programs execution in distributed processing environments.

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Dr. Izzatdin Abdul Aziz is a researcher at the High Performance Cloud Computing Centre (HPC3) in The Universiti Teknologi PETRONAS (UTP), where he focuses in solving complex upstream Oil and Gas (O&G) industry problems from the view point of computer sciences. He is also a lead researcher for the Data Analytics and Intelligence Lab at UTP. Dr. Izzatdin currently serves as the deputy head of the Computer and Information Sciences Department in UTP. He obtained his Ph.D in Information Technology from Deakin University, Australia working in the domain of hydrocarbon exploration and cloud computing. Prior to his Ph.D, Izzatdin earned his Master's degree in Information Technology specializing in Computer Networks from the University Of Sydney, Australia. Dr. Izzatdin has secured and delivered numerous computing-related O&G projects mainly relating to seismic data processing and implementation of workflows for processing hydrocarbon exploration dataset on cloud based systems. His research is mainly funded by the Petroleum Research Fund, PETRONAS, Yayasan UTP fund and The Malaysian Ministry of Higher Education. He is currently the editor-in-chief for the Jurnal Teknologi Special Issue Advances in Big Data Analytics on High Performance Computers and Scalable Systems, editorial board member of Journal of Advance Computational Intelligence with Big Data, member of the International Association of Engineers and the Society of Digital Information and Wireless Communication.

Dr. Jafreezal Jaafar is currently an Assoc. Prof. and Dean of Faculty of Science & Information Technology (FIST) at Universiti Teknologi PETRONAS, Malaysia. Previously, he served Computer and Information Sciences (CIS) department as a Head of department for few years. He holds a PhD degree from University of Edinburgh, UK (2009). He did MAppSc in IT from RMIT University, Australia (2002) and bachelor's degree in Computer Science from Universiti Teknologi Malaysia (1998). His main research areas include Big Data Analytics, Soft Computing and Software Engineering. He has managed to secure several number of research projects from industry and government agencies. Based on his publication tract record, he had been appointed as a Chief Editor and reviewer for several journals. He also possess a great experience for organizing and participating as a technical chair or member for several international conferences. He was appointed as an Executive Committee member for IEEE-Computer society, Malaysia-chapter in year 2016 and 2017.

Abdul Rehman Gilal is a faculty member of Computer Science department at Sukkur IBA University, Pakistan. He has earned a PhD in Information Technology from Universiti Teknologi Petronas (UTP), Malaysia. He has been mainly researching in the field of software project management for finding the effective methods of composing software development teams. Based on his research publication track record, he has contributed in the areas of human factor in software development, complex networks, databases and data mining, programming and cloud computing.