Matlab Software in PC to Replace Embedded System Used in Seismic Exploration

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***Abstract*—Seismic exploration is the search for underground storage of crude oil, natural gas and minerals, commercially viable, through registration, processing and interpretation of artificially induced acoustic waves, and includes processes and activities such as seismic data; drilling; technical team to get data. The importance of this activity lies in the information that these sites may have before making such a large investment in your piercing. The seismic exploration is a complex technology that combines advanced physics, mathematics and computing. The Backup software systems used in seismic exploration is an expensive and complex system. Therefore, in this paper we present a series of algorithms that run on a Personal Computer, are written in Matlab code, to date, This Software is rapidly gaining users to solve problems as presented, because the costs will be dramatically reduced. This is achieved by algorithms which are grouped into a small number of toolboxes Matlab functionality and extends, confirm the approach undertaken within the implementation of a dynamic and easy to use method, especially economical compared to the systems currently used in seismic exploration.**

***Index Terms*—seismic, exploration, Matlab**

I. Introduction

Seismic methods represent one of the geophysical techniques more important today [1]. His dominance over other imaging methods due to its high resolution and high penetration; It is mainly used in oil exploration, locate gas fields, which subsequently be drilled and exploited.

Unlike mining, seismic surveys in no rocks break, but a seismic wave generated by the detonation of an explosive charge at a given depth.

Seismic exploration methods basically involve the same types of measurements performed in symbology earthquakes. However, the power sources are controlled and mobile and offset are relatively small. Many seismic work consisting of a continuous coverage throughout the process wherein the successive response land portions shown along profiles [2].

Seismic exploration includes the following processes and activities:

- Review of available seismic data.
- Collecting, processing and interpretation of 2D seismic in all concessions.
- Drilling an exploratory well to evaluate the characteristics of the deposit. The technical team obtains data both during drilling, and subsequently, with information collected through records, analysis of samples taken and production testing [3].
- Drilling of a second well with a possible horizontal section to carry out an analysis and production tests in more detail [4].

Today, however, oil exploration rests almost entirely on some modern varieties of seismographs employing the method of reflection as a key element for the acquisition of seismic data [5]. Recent advances in geophysical exploration for oil exploration are rooted in the refinement of the instrumentation used today, and the advancement of computers used to process the large volume of field data.

A. *Seismic Exploration*

The objective of seismic exploration is to deduce information about the characteristics of the rocks, strata, after arrival times and variations in amplitude, frequency, phase and waveform of seismic waves generated by explosives or other energy sources [6].

The artificial seismic energy is generated in the ground by vibrating mechanism mounted on special trucks.

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Seismic waves are reflected and refracted in rock formations underground and travel back to Sounders called geophones [7].

Travel times (measured in milliseconds) of seismic energy return, attached to the information obtained and other exploratory wells, help geoscientists to calculate the structure (folds and faults) and stratigraphy (rock type, sedimentary environment and fluid content) of underground formations, and determine the location of potential drill targets.

Seismic exploration, whose study is performed with long and complex procedures, without leaving behind the high costs of the technologies developed in generating software and computer systems responsible for developing the analysis of these seismic studies [8].

In consequence of these needs presented by the industry has been forced to interact with other disciplines to create progress, tools and methods that enable the best performance of its operations, which is why a number of facilities for the new seismic modeling have been created in Matlab. These include ray tracing for v (z) for modeling entire waveform.

Ease ray tracing v (z) is flexible and fast, determines travel times in half horizontally isotope. This can shoot rays or works fans colon ray tracing. (This means that a ray is traced through a specific point of origin and endpoints).

Ray shot means that the starting point and the firing angle of the ray are prescribed but not the end point). Functions are provided for automatic determination of travel time of the waves in the register of geometric shot for PP, SS, PS and SP modes [9]. With a slight effort arbitrary multimodal can be traced and other settings such as Vertical Seismic Profile (PSV) can be modeled.

Ray tracing v (x, z) can shoot rays through a field of arbitrary variable speed (2D) and determine travel times of waves. This works to solve the differential equation rays on a spatial mesh. The rays are aimed at constant time increments through the mesh using a solution of Runge-Kutta 4th order.

II. Methodology

Matlab has not been available until the mid 80's and before that FORTRAN language was selected for computational science processes. However the C language was also a possibility that you consider only disadvantage handling complex numbers, In addition to advantages Fortran C i miss like structures, pointers and dynamic memory allocation.

Developed Matlab package that was familiar Linpack Fortran programs as a robust collection of tools for linear algebra. Thus Matlab also present a new programming language oriented vectors, an interactive graphical environment and application. These features offer enough advantages [10].

A. Programming Tools

This section provides some strategies to effectively use Matlab to explore and manipulate seismic data sets, in combination with the tools and toolboxes developed by Crewes. Matlab has two basic programming constructs: scripts and functions:

1) Scripts

A script is the simplest structure Matlab programming, is nothing more than a sequence of correct commands synthetically have been written in a file, which must end in extension, must appear in the search path. When you write the file name without the .m extension in the Matlab prompt, the program will search your path for files with .m extension with the name and execute the commands contained therein. If you have questions you can use the command, which will show the full path of the file search will be executed.

2) Functions

These functions are simply a list of MATLAB running on space-based work. Functions are executed in their own separate work space communicating with input and output variables in the workspace base.

III. Results and Discussion

Actually functions are inherently numerical speed because these are derived from an experiment. The conversion of said numerical speeds one form to another is often necessary in data processing and software tools are required for this purpose.

Two alternative approaches are proposed (1) Adjust speed numerical functions with polynomial order and perform the necessary integration using polynomial integration rules or (2) implement a plan of numerical integration for the conversion formulas; the latter approach is that we take in this project.

Five functions are available for converting speed functions from one form to another, there is also a useful function plotting to draw consistent lines.

- Computes the vertical traveltime giving speed versus depth intervals. $v\text{int}2vave$ Speed becomes average speed intervals.
- $vave2v\text{int}$ Becomes the average speed to speed intervals.
- $v\text{int}2t$ $v\text{int}2vrms$ Converts rms velocity intervals.
- $vrms2v\text{int}$ Converts the rms speed speed intervals.

As seismic traces, speed functions are specified by prescribing two vectors, speed functions are specified by prescribing two vectors, one for speed and one for the depth or time applied.

A. Snell's Law Applied in Matlab

It is a relationship that governs the angles of reflection and refraction of the wavefronts(or equivalent ray tracing) speed interfaces. Consider Fig. 1 shows a planar periodic wave propagating through a planar interface between two media $\lambda_1 = v_1/f$ and v_2 of wavelength speed v_1 $\lambda_2 = v_2/f$ a planar interface between two media of wave velocity length y. The only way for the two systems wavefront to stay constantly through the interface and still have different wavelengths, is to have different angles to the interface. The relationship between these angles follows a consideration of apparent speed.

Since the frequency f does not change (this is a property of the propagation of a linear wave). Working with rotational coordinates (x', z') apparent speed $v_{x'}$ should give the same result when assessed using v_1 and θ when used as v_2 y ϕ therefore.

$$v_{1x'} = \frac{v_1}{\sin\theta} = v_{2x'} \equiv \frac{v_2}{\sin\phi} \quad (1)$$

This result is called Snell's law. The angles involved in Snell's law can be considered as the angles between the wavefront and the interface or between the stroke-ray and the normal to the interface.

In or acoustic medium, with half wave propagation, is that the angle of incidence and reflection are equal. However, in an elastic medium, the incident and reflected waves can be any type of P wave or S wave, a P wave incident as an S wave by reflecting the state of Snell's law [11].

$$\frac{\sin\theta\, p}{v\, p} = \frac{\sin\theta}{v\, s} \quad (2)$$

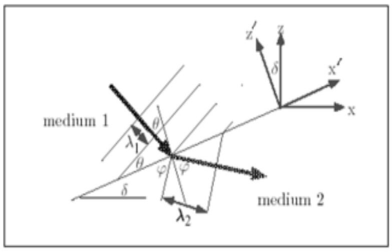

Figure 1. Snell's law of the physical requirement that the apparent velocity along an interface remains.

B. Ray Tracing in Half $v(z)$

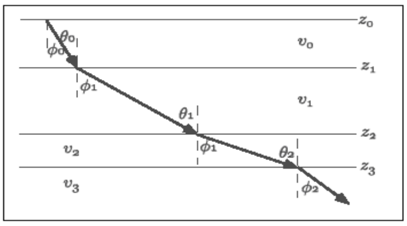

Figure 2. Half, $v(z)$ all interfaces are horizontal velocity and beam propagation is particularly simple.

An environment $v(z)$ is one where $\partial_x v = \partial_y v = 0$ all interfaces and speed are horizontal. An environment is one where all interfaces and speed are horizontal. In this case Snell's Law says that the apparent horizontal speed of the wavefront associated with the beam is preserved. Using the notation of Fig. 2, this must remain for the interface j^{th} as:

$$\frac{\sin\theta\, j-1}{v\, j-1} = \frac{\sin\phi\, j}{v\, j} \quad (3)$$

So all speed interfaces are horizontal, $\theta\, j = \phi\, j$ then

$$\frac{\sin\theta\, j-1}{v\, j-1} = \frac{\sin\theta\, j}{v\, j} \quad (4)$$

This analysis should be repeated in any other interface to a similar conclusion.

Therefore the amount $p = \sin\theta\, j / v\, j$ is kept from the beginning to the end in the entry wave propagation. P is generally referred to beam parameters from which are a unique constant for any ray. This analysis generalized to a continuous variation of v whit z, therefore:

$$P \equiv \frac{\sin(\theta(z))}{v(z)} = \text{Constant for any ray Snell's law} \quad (5)$$

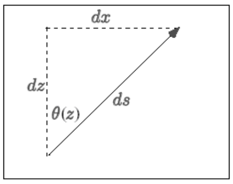

Figure 3. A differential beam element, being displaced in depth in an angle to the horizontal.

A general expression for the traveltime Fig. 3 shows a differential element of lightning. From this geometry we obtain.

$$dx = \tan(\theta(z))dz \quad (6)$$

$$dt = \frac{ds}{v(z)} = \frac{dz}{v(z)\cos(\theta(z))} \quad (7)$$

Snell's law to replace the trigonometric function using $pv(z) = \sin(\theta(z))$ get:

$$dx = \frac{pv(z)}{\sqrt{1-p^2v^2(z)}}dz \quad (8)$$

$$dt = \frac{dz}{v(z)\sqrt{1-p^2v^2(z)}} \quad (9)$$

Microscopic expressions for tracing rays are obtained by simply integrating these results. For the displacement of a beam between depths z_1 and z_2 horizontal distance moved becomes:

$$x(p) = \int_{z1}^{z2} \frac{pv(z)}{\sqrt{1-p^2v^2(z)}}dz \quad (10)$$

and the total traveltime is:

$$t(p) = \int_{z1}^{z2} \frac{dz}{v(z)\sqrt{1-p^2v^2(z)}} \quad (11)$$

Given a function of speed and ray parameter we can compute exactly the horizontal distance (offset) and the traveltime for a ray that travels between two depths. After a new and refined ray arc can be constructed and the process repeated until a beam is found produce the desired offset within the specified tolerance (called capture radius).

If the medium $v(z)$ is discretely separated into layers, which continuously changes, the form of the sum of Equation 10 and 11, are more appropriate:

$$x(p) = \sum_{k=1}^{n} \frac{pvk}{\sqrt{1-p^2v^2k}}\Delta zk \quad (12)$$

$$t(p)=\sum_{k=1}^{n}\frac{\Delta zk}{vk\sqrt{1-p^2v^2k}} \quad (13)$$

1) Measuring beam parameters

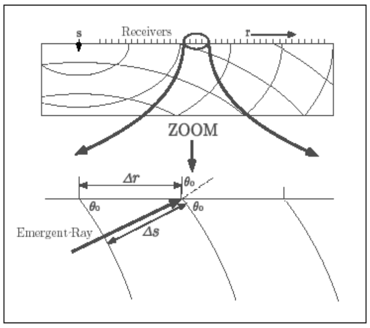

Figure 4. Beam parameters can be measured directly this is possible by measuring the delay or the delay between the arrivals of the wave front in successive receivers.

Given a seismic source parameters of the beam to the next arrival of waves in the spread of the receiver can be estimated by measuring the apparent horizontal velocity of each wave (Fig. 4) the emerging angle θ_0 of a ray arriving at a particular pair of receptors is:

$$\sin\theta_0=\frac{v_0\Delta t}{\Delta r} \quad (14)$$

where v_0 the instantaneous velocity is immediately below the receivers, Δr that is the spacing between receivers y Δt the time delay between the arrival of the wavefront r and $r+\Delta r$. To arrive at this expression, any wavefront curvature has been assumed to be inconsequential at the local site of measurement.

According to equation5 beam parameters are given by θ_0/v_0, so:

$$\frac{\Delta t}{\Delta r}=\frac{1}{v_r}=\frac{\sin\theta_0}{v_0}=p \quad (15)$$

where v_r is the apparent horizontal speed in the measurement location.

P is generally expected that changes position due to changes in the emergence angle and because of the lateral variation in the instantaneous velocity. Events horizontal, vertically traveling wave when it reaches the array of receivers have a beam parameter 0. The wave moving horizontally across the array has beam parameters $1/v_0$ and a seismic graph (x, t) has the maximum possible slope.

Even the wave fronts are vertical, the slope in the weather section cannot exceed $1/v_0$. Taking into account the sample, the range of possible values for the parameter of the beam is $-v_0^{-1}\le p\ge v_0^{-1}$.

This maximum tilt in space (x, t) is a fundamental characteristic of a seismic time section. Assuming a value for v_0 during the data processing means that any event with steeper slopes which v_0^{-1} is interpreted as a nonphysical and must be rejected.

Since the apparent velocities can also be expressed in space (k_x, f) as f/k_x this phenomenon means that the space (k_x, f) is divided into segments allowed and forbidden regions.

C. When Lightning Strokes $v=v_0+cz$

This is not difficult to integral equations 10 and 11 for the case of instantaneous velocity that increases linearly with depth (depending on the universal speed). Leaving, $v(z)=v_0+cz$ z = 0, z = z, the result is equal to:

$$x(z,p)=\frac{1}{pc}\left[\sqrt{1-p^2v_0^2}+\sqrt{1-p^2\{v_0+cz\}^2}\right] \quad (16)$$

and

$$t(z,p)=\frac{1}{c}\ln\left(\left[\frac{v_0+zc}{v_0}\right]\left[\frac{1+\sqrt{1-p^2v_0^2}}{1+\sqrt{1-p^2\{v_0+cz\}^2}}\right]\right) \quad (17)$$

Slot nick shows that equation 16 describes an arc of a circle, $1/(pc)$ having radio and center $x_0=\sqrt{1-p^2v_0^2}/(pc)$ and $z_0=-v_0/c$ As equation 16 describes a beam like 0 to depth z.

Since the speed is always increasing in this case the angle Snell's laws are always longer obtained as a deeper beam. Eventually the beam is attenuated when $\theta(z)=\sin^{-1}(pv(z))=90°$, and turns upward. Therefore, the depth at which a ray hits bottom, called the turning point is obtained from:

$$z_{\max}=\frac{1-pv_0}{pc} \quad (18)$$

The path full beam to a beam that reaches its turning point and then returns to the surface must have two values x for each z, so the function $x(z)$ is a doubly mathematical value. Either way it is $z(x)$ still only valued so full stroke ray computed as easy as possible solving equation 16 that z looks like:

$$z=\frac{1}{pc}\left[\sqrt{1-\{pcx-\cos\theta_0\}^2}-pv_0\right] \quad (19)$$

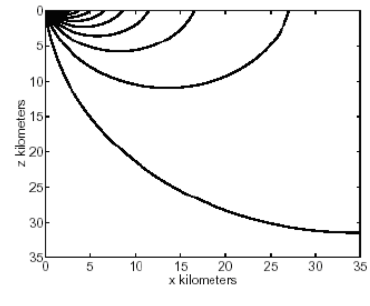

Figure 5. A selection of lightning strokes is shown for the function of the universal speed Fig. 6. The code creates this chart.

The fragment of code implements the equation 19 to create the deployment beam path shown in Fig. 5. This code provides a range of horizontal distance and a series of shooting angles in lines 1-3.

After looping on the desired ray depth is calculated for each element of the vector x. Many of these rays do not cover the full range x. Equation 19 returns a complex number to a distance x that cannot be achieved by a particular ray. 11-13 lines looking for these points and replace their depths NaN .

The code also generates values z that are negative so lines 15-18 set this to NaN . The bending beam in Fig. 6 is much more realistic than a simple calculation using constant velocity rights rays. It is shown that much of the energy of a seismic source cannot penetrate very deep because it is rotated by the refraction effect.

All beam paths are obviously circular arcs whose centers are moved to the right and diminish the beam parameters.

Slot nick also derives expressions for wave fronts (surfaces of constant traveltime) and the samples are circles whose centers are along the axis z :

$$z_{w0} = \frac{v_o}{c}\left[\cos h(cT) - 1\right] \tag{20}$$

where T is the traveltime defining the wavefront. Each circular wave front has a radius of:

$$r = \frac{v_0}{c}\sin h(cT) \tag{21}$$

3.1 Code This code implements the equation 19 and Fig. 5, makes

```
1x=1:50:35000;
2vo=1800;c=.6;nrays=10;
3thetamin=5;thetamax=80;
4deltheta=(thetamax-thetamin)/nrays;
5zraypath=zeros(nrays,length(x));
6 for k=1:nrays
7theta=thetamin+(k-1)*deltheta;
8p=sin(pi*theta/180)/vo;
9cs=cos(pi*theta/180);
10z = (sqrt( 1/(p^2*c^2) - (x-cs/(p*c)).^2) - vo/c);
11ind=find(imag(z)~=0.0);
12if(~isempty(ind))
13z(ind)=nan*ones(size(ind));
14 end
15 ind=find(real(z)<0.);
16 if(~isempty(ind))
17z(ind)=nan*ones(size(ind));
18 end
19zraypath(k,:) = real(z);
20 end
21figure;plot(x/1000,zraypath/1000);flipy;
22xlabel('x kilometers');ylabel('z kilometers')
```

End of Code

Code 3.2.2 This code assumes that the code 6.11.1 has actually been raced and comes from this to calculate and plot the wavefronts, as a result we Fig. 5.

```
1 zw=0:50:30000;
2nwaves=10;tmax=5;
3xwavefront=zeros(nwaves,length(zw));
4times=linspace(0,tmax,nwaves);
5 zo=zeros(1,nwaves);
6 for k=1:nwaves
7 zo(k)=vo*(cosh(c*times(k))-1)/c;
8r=vo*sinh(c*times(k))/c;%radius
9 xw=sqrt(r.^2-(zw-zo(k)).^2);
10 ind=find(real(xw)<0.);
11 if(~isempty(ind))
12xw(ind)=nan*ones(size(ind));
13 end
14 ind=find(imag(xw)~=0.0);
15 if(~isempty(ind))
16xw(ind)=nan*ones(size(ind));
17 end
18xwavefront(k,:) = real(xw);
19 end
20figure;plot(xwavefront/1000,zw/1000);flipy;
21xlabel('xkilometers');ylabel('z kilometers')
```

End of Code

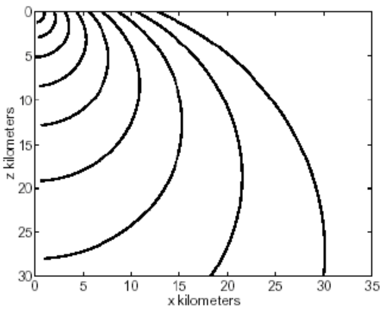

Figure 6. A number of wavefronts associated with strokes of lightning in Fig. 3. This was created with the code 3.1.

3.2. Calculate code 10 and plotted wave fronts travel times for a number of 0 to 5 sec. For each wave front strategy is to calculate the center of circle of the wave front (line z) and its radius (line 8).

Then, to set the number of depths (line 1) the horizontal position is calculated from the equation of a circle (line 9). As in the case of strokes of lightning, this result is both complex and negative values which are found in series NaN (lines 10-17).

Resulting wave fronts clearly show the effects of increasing velocity with depth, being more closely than attenuated in shallow depths deeper depths. Fig. 6a superimposed lightning strokes and the wave fronts and uses the command *axis equal* to ensure aspect ratio 1: 1. Clearly strokes rays are normal to the wave fronts.

D. Matlab Tools for General Raytracing (1)

Either way more accurate results are often desired for complicated $v(z)$ since these are the result of large measurements. In this case the only way to proceed is through a numerical implementation of the equations 10 and 11 or more correctly the equations 12 and 13. Usually it is desired to treat rays between two specific points, as a source and a receiver may reflect a specific depth.

For determination, assume that it is desired to trace rays, P-P reflection $z_r = 2000m$ a reflector and an arbitrary means $v(z)$ and an offset of 100 to 2000 m. P-P from a completely symmetrical beam follows a trajectory (if a source and receiver are at the same depth), this is enough to draw a ray of z = 0 to z = z_r offset x / 2 and then double the results.

If the speed is constant, then the simple geometry predicts peel off angle $\theta_0 = \arctan(x/(2zr))$ y therefore the ray parameter is found trivial. To increase the velocity with depth, the take-off angle will be smaller than expected with constant speed, while to decrease the velocity with depth the situation is reversed.

In the general case, the takeoff angle and therefore the ray parameter cannot be found analytically.

There are seven features and a demonstration script provided raytracing $v(z)$:

- ***Rayfan*** Shoot a range of parameters paying ray beam to $v(z)$
- ***Rayfan_a*** Similar to rayfan but rays are specified by angle.
- ***Shootray*** Similar to rayfan but with less error checking (faster)
- ***Traceray_pp*** Draw a reflection P-P (or S-S) to $v(z)$
- ***Traceray_ps*** Draw a reflection P-S (o S-P) to $v(z)$.
- ***Traceray*** Giving an arbitrary ray trace code torque beam $v(z)$.
- ***Drawray*** Interactive demonstration of ray tracing facilities $v(z)$.

3.3 The code shootray function fires a ray range as defined for the row vector p of $z(1)$ to $z(end)$ by the velocity model defined by the column vectors v y z.

```
function [x,t]=shootray(v,z,p)
code not displayed see shootray.m
iprop=1:length(z)-1;
sn = v(iprop)*p;
[ichk,pchk]=find(sn>1);
[ichk,pchk]=find(sn>1);
cs=sqrt(1-sn.*sn);
vprop=v(iprop)*ones(1,length(p));
thk=abs(diff(z))*ones(1,length(p));
if(size(sn,1)>1)
x=sum( (thk.*sn)./cs);
t=sum(thk./(vprop.*cs));
else
x=(thk.*sn)./cs;
t=thk./(vprop.*cs);
end
%assign infs
if(~isempty(ichk))
x(pchk)=inf*ones(size(pchk));
t(pchk)=inf*ones(size(pchk));
end
```

End of Code

Code 3.4. This code illustrates a reflection P-P y P-S linear gradient in a medium. This creates Fig. 8 y Fig. 9.

```
zp=0:10:3000;vp=1800+.6*zp;vs=.5*vp;zs=zp;% velocity model
zsrc=100;zrec=500;zd=3000;%source receiver and reflector depths
off=1000:100:3000;caprad=10;itermax=3;%offsets, cap radius, and max iter
pfan=-1;optflag=1;pflag=1;dflag=2;% default ray fan, and variousflags
% create P-P reflection
figure;subplot(2,1,1);flipy;
[t,p]=traceray_pp(vp,zp,zsrc,zrec,zd,xoff,caprad,pfan,itermax,optflag,...
pflag,dflag);
title([’Vertical gradient simulation, P-P mode zsrc=’ ...
num2str(zsrc) ’ zrec=’ num2str(zrec)])
line(xoff,zrec*ones(size(xoff)),’color’,’b’,’linestyle’,’none’,’marker’,’v’)
line(0,zsrc,’color’,’r’,’linestyle’,’none’,’marker’,’*’)
grid;xlabel(’meters’);ylabel(’meters’);
subplot(2,1,2);plot(xoff,t);grid;
xlabel(’meters’);ylabel(’seconds’);flipy
% P-S reflection
figure;subplot(2,1,1);flipy;
[t,p]=traceray_ps(vp,zp,vs,zs,zsrc,zrec,zd,xoff,caprad,pfan,itermax,
optflag,pflag,dflag);
title([’Vertical gradient simulation P-S mode zsrc=’ ...
num2str(zsrc) ’ zrec=’ num2str(zrec)])
line(xoff,zrec*ones(size(xoff)),’color’,’b’,’linestyle’,’none’,’marker’,’v’)
line(0,zsrc,’color’,’r’,’linestyle’,’none’,’marker’,’*’)
grid;xlabel(’meters’);ylabel(’meters’);
subplot(2,1,2);plot(xoff,t);grid;
xlabel(’meters’);ylabel(’seconds’);flipy;
```

End of Code

As shown in the code shotray 3.3 has three inputs respectively v, z and p which are column vectors of the speed and depth of the row vector and lightning parameters. The ray vector defined p, is $z(1)$ to $z(end)$ use the tracing speeds v. The velocity model is assumed to be constant $v(k)$ parts, with speed and persisting source to $z(k)$ a $z(k+1)$ constant.

Consequently the final speed v is irrelevant to shootray, and line 3 provides an index table for the relevant speeds. Lines 3 through 8 are key to the efficiency of shootray. In line 3 is $v(iprop)$ a column vector of length m and p is a row vector of length n .

This product of a matrix $m\,x\,1$ representing $v(z)$ a matrix $1\,x\,n$ representing matrix p is $m\ x\ n$ $\sin\theta = pv(z)$ called sn . The column represents $\cos\theta(z)=\sqrt{1-p^2v^2(z)}$ k^{th} the sn product $pc(z)$ for the ray parameter k^{th} . Line 6 builds the matrix cs representing. Lines 7 and 8 the matrix $m\ x\ n$ constructed, $vprop$ and thk it represents $v(z)$ and Δz for each ray.

Since these amounts are the same for each ray, this is represented by matrices with identical columns. So, we have four matrices $m\ x\ n$ with z as coordinate as the coordinate row p and column.

Not all of these combinations z and p can you correspond to physical rays as the beam penetration depth is limited. Line 5 detects these nonphysical combinations finding any value that $pv(z)$ is larger than 1.

The ray tracing is completed on lines 9 through 15 and a statement *if* is used to handle the case of a single layer. Using the matrix $m\ x\ n$, thk, sn, cn computes line 10 using equation 16 operator. * for expression as $pvk\Delta zk/\sqrt{1-p^2v_k^2}$ a matrix form $m\ x\ n$.

Then as discussed in section 3.8, the function is used to complete the discrete sum approximating the integral in equation 11. When applied to a matrix, sum, this produces a row vector is the sum gives each column of the matrix.

This behavior determines the construction of arrays $m\ x\ n$ in each column p constant. The statement *if* is required for the case of a single layer behavior also sum. If only one layer, then the arrays $m\ x\ n$ are all row $1\ x\ n$ vectors. When a row vector is sum given, they add entries to obtain a single value instead of adding columns of length 1

The statement if prevents this behavior completely sum omitted in the case of a single layer. The final step, the online17 to 20 assigned to these non-physical values that were previously marked on line 5.

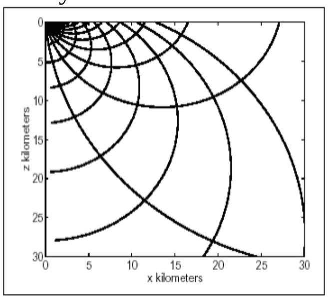

Figure 7. This figure superimposed ray traces in Fig. 8 on the wavefronts of Fig. 5.

Instead of colon problem, a problem one way is applied to determine the layers on top and below the reflector locate them in the order they are found (Fig. 7). The layers containing the source, receiver and reflector are adjusted shootray thicknesses can be used to trace $z(1)$ and $z(end)$ ray (Fig. 8).

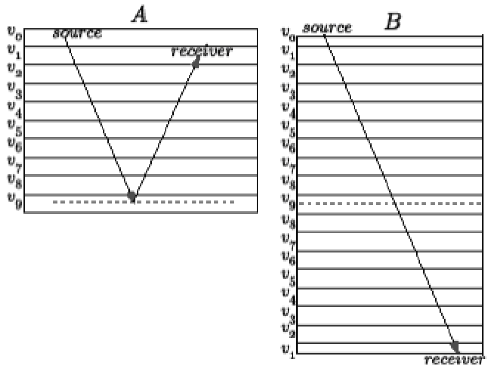

Figure 8. (A) A PP reflection between a source and a receiver at different depths. (B) The ray tracing in an equivalent way to the beam in two ways, as shown in (A). The dotted line is the reflector in both cases.

ENCODING equivalent can always be constructed for a beam to change mode (between P and S) and take any number of extra limits. In the above case, just the equivalent ENCODING must use the correct speeds. In the latter case the equivalent layered may contain many repetitions of a section. This is a simple scheme couple computing any lightning $v(z)$.

Stroke functions colon ray tracing rays can all one starting point to multiple receivers simultaneously. That is, to be sectored for profit simple source. Although the depth of the source need not equal depth of the receiver, if multiple receivers are specified, these should be at the same depth.

This means that the geometries of a vertical seismic profile should be handled by calling the ray tracer separately for each receiver depth. The three programs repeated until the receivers have a ray tracing within the radius of capture of position or a maximum number of interactions is reached.

Capture radius is the radius of an imaginary circle of each receptor which, if lightning strikes within this, is considered good enough for the receiver. If the flag is *optflag* set to 1, then the actual traveltime and ray parameter are captured directly interpolated between the beam and the next closest. If *optflag* zero, then the captured beam is used directly.

Different ray tracers, codes here may reflect or convert so lightning in any depth not only in a boundary layer. However this is not physically correct, this is allowed in the common practice of operation reflectivity propagation model.

The idea is that the rays are traced through a simplified background which is chosen to give sufficiently accurate traveltime for the task at hand. The reflections are assumed to come from a level of detail beyond that required for $v(z)$ the calculation of traveltime. For example, a linear variation of constants to be used with locally determined as a function of line speed.

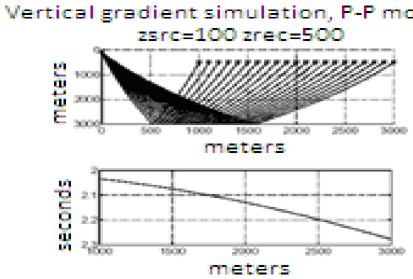

Figure 9. A PP reflection is shown for an average background $v_p(z) = 1800 + .6z m/s$.

3.3 exhibits code ***traceray_pp*** and ***traceray_ps*** using modeling traceray_ps traceray_pp and PS and PP reflections with universal speed function as the background medium. The results are shown in Fig. 9 and Fig. 10.

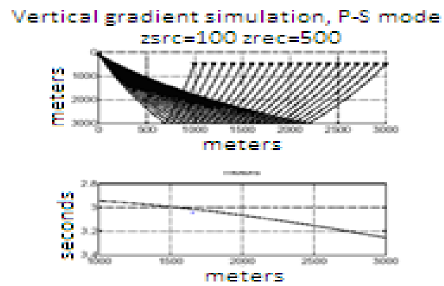

Figure 10. A PS reflection is shown for an average background de $v_s(z) = 900 + .3z$.

Line 1 defines models and with a speed of v_p and v_s a v_p / v_s 2. Lines 2 and 3 provide the basic geometry of the source, receiver and reflector. The capture range is set to 10% of the receiver spacing and the maximum number of interactions is set to 3 which is suitable for the media attenuated.

The call to traceray_pp is on the line 7 and the final parameter instructs the program to draw the rays within the window of the current figure. Lines 9 and 10 symbols drew the source and the receiver and the traveltime plotted line 12 in the lower half of Fig. 6a

Lines 15 through 22 are very similar, except that ***traceray_ps*** is called to create a PS reflection. A PS reflection could be created by reversing the order of the arguments of speed (egtraceray_ps (vs, Zs, vp, zp ...). Similarly one SS reflection can be modeled using ***traceray_pp*** and supplying with the functions of S-wave velocity.

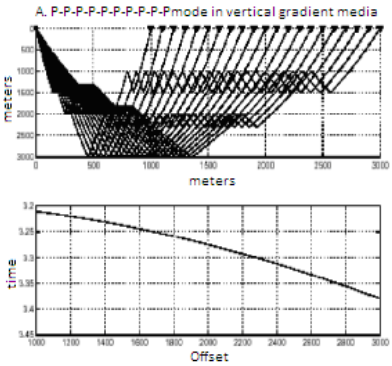

Figure 11. A multiple and complicated beam is shown that P beam remains everywhere

Code 3.5: There is a demonstration of the use of traceray to compute multiple paths and multiple modes limits. This code creates Fig. 11.

E. Application of the Method

The key idea here is to use a beam code to define the depths and types of mode different parts of ray tracing, ray code is a matrix $n\ x\ 2$ with the first column being a list of depths and the second containing any 1 whole (P-wave) or 2 (wave-S).

The code matrix of [0 1; 1000 2; 800 2, 1000 1; 100 1].The final entry in column two is pointless. Code 3.6 shows this facility creating a complicated multi-beam P limit (no conversion mode) on line 8 and a multimode beam line 17.

Code 3.5: There is a demonstration of the use of ***traceray*** to compute multiple paths and multiple modes limits. This code creates Fig. 10 y Fig. 11.

1 zp=0:10:3000;vp=1800+.6*zp;vs=.5*vp;zs=zp;	13subplot(2,1,2);plot(xoff,t);
2 xoff=1000:100:3000;	14 grid;flipy;xlabel('offset');ylabel('time')
3 caprad=10;itermax=3;%cap radius, and max iter	15
4 pfan=-1;optflag=1;pflag=1;dflag=2;% default ray fan, and various	16 raycode=[0 1;1500 2;1300 2;2000 2;1800 2;3000 1;2000 1;2300 1;1000 1; 1500 2; 0 1];
5	17 figure;subplot(2,1,1);flipy
6 raycode=[0 1;1500 1;1300 1;2000 1;1800 1;3000 1;2000 1;2300 1;1000 1; 1500 1; 0 1];	18[t,p]=traceray(vp,zp,vs,zs,raycode,xoff,caprad,pfan,itermax,optflag,pflag,dflag);
7 figure;subplot(2,1,1);flipy	19title('A P-S-S-S-S-P-P-P-P-S mode in vertical gradient media');
8[t,p]=traceray(vp,zp,vs,zs,raycode,xoff,caprad,pfan,itermax,optflag,pflag,dflag);	20xlabel('meters');ylabel('meters')
9 title('A P-P-P-P-P-P-P-P-P-P mode in vertical gradient media');	21 line(xoff,zeros(size(xoff)),'color','b','linestyle','none','marker','v')
10 xlabel('meters');ylabel('meters')	22line(0,0,'color','r','linestyle','none','marker','*');grid
11line(xoff,zeros(size(xoff)),'color','b','linestyle','none',' marker','v')	23subplot(2,1,2);plot(xoff,t);
12 line(0,0,'color','r','linestyle','none','marker','*');grid	24 grid;flipy;xlabel('offset');ylabel('time')

End of Code

IV. CONCLUSIONS

Codes raised, let us see in the graphs found, the path of a range of rays from the source, until his return to collection points (geophones), and their points of reflection, provide velocity information acquired in all its path, so we can determine what depths these wave fronts and scroll through deflect.

Importantly, the study is based on analysis of a trigger point therefore can only work with a wave front at a time, which presents a limiting, since a seismic study includes an extensive array of geophones lines large areas, offsetting comparing the quality of the results of the wave front, with the high cost of acquisition as sophisticated as those used in the software industry.

REFERENCES

[1] A. Strahler, *Geology Physic*, Omega Editions, Barcelona, 1986, pp. 629.

[2] E. S. Robinson, *Basic Physical Geology*, EditionLimusa (Mexico), 1990, pp. 699.

[3] M. Orozco, J. Azañón, A. Azor, and Alonso-Chaves, *Physical Geology*, 2nd. Edition, Thomson Editors, Madrid, Spain, 2003, pp. 302.

[4] J. W. Rogers and A. S. Adams, *Geology*, Omega, Ed., *Barcelona* 1969, pp. 336.

[5] B. Melendez and J. Fuster, *Geology*, *9th edition*, Thomson, Ed., Madrid, Spain, 2003, pp. 911.

[6] A. Udias, *Introduction to Seismology and Internal Structure of the Earth*, Madrid, Spain, 1971.

[7] W. Griem, *Deriva Continental and Tectonic of Places*, H. Blume Ed., Madrid, 1976, pp. 268.

[8] K Bullen, *An Introduction to the Theory of Seismology*, Third ed., Cambridge Univ. Press, 1963.

[9] Y. Tsai and Y. K. Aki, "Precise focal depth determination from amplitude spectra of surface waves," *J. Geophys. Res.*, vol. 75, pp. 5729-5733, 1970.

[10] R. Burridge, *Some Mathematical Topics in Seismology*, University New York, EUA, 1976.

[11] G. F Margrave, *Numerical Methods of Exploration Seismology with Algorithms in Matlab* (NMES), 2003.

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