Example how to use functions from MLIB/CRS library

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Library MLIB/CRS includes codes that allow:

- to compute analytically traveltime of reflection waves for a number of models;
- to compute wavefield attributes associated with the central ray;
- to compute traveltime corrections as predicted by CRS, DSR, nCRS and i-CRS approximations (both matlab and C++ realizations)

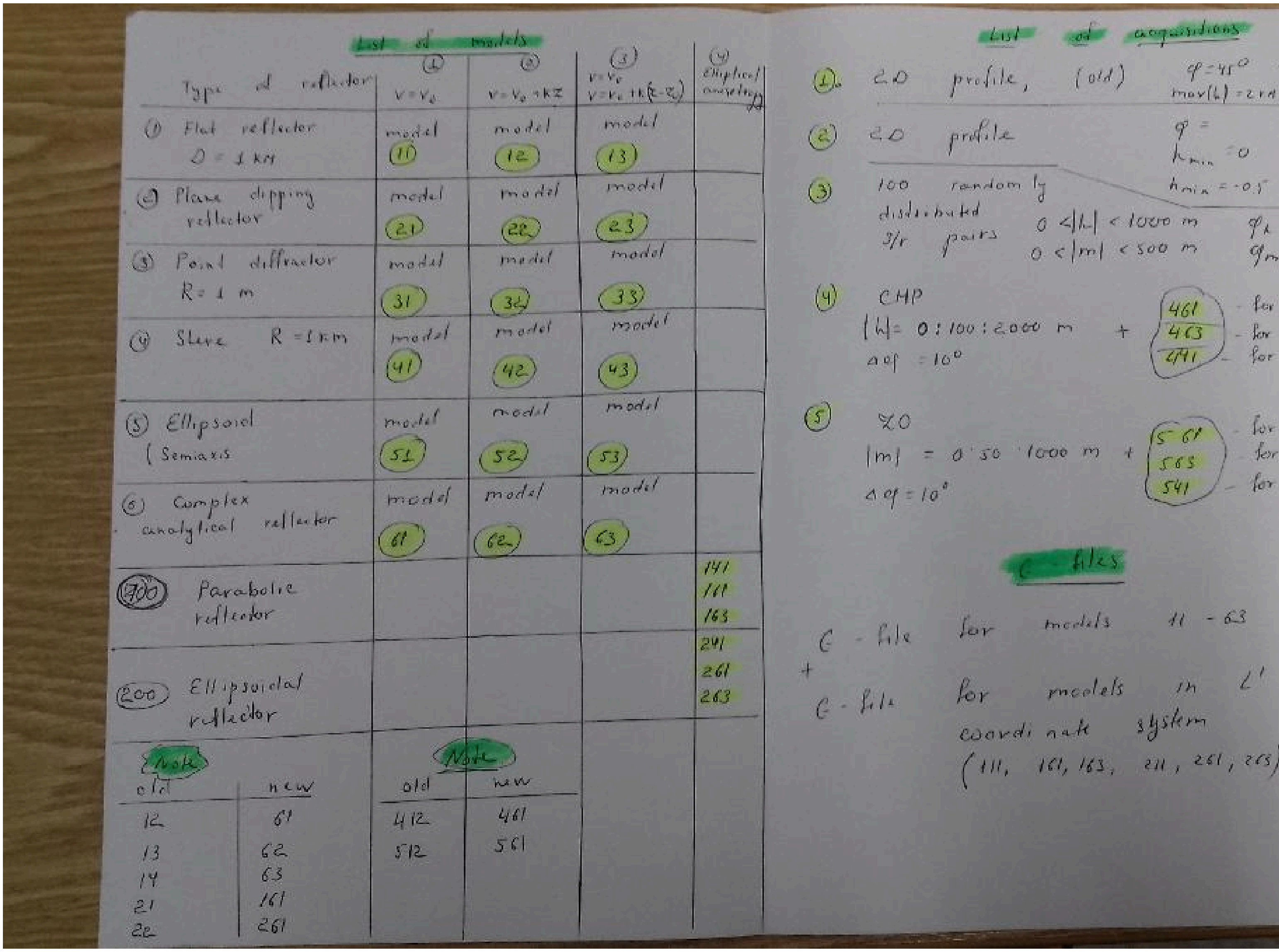
See detailed explanation in Chapter 3, Abakumov, I. (2017). Systematic analysis of double-square-root-based stacking operators

http://ediss.sub.uni-hamburg.de/volltexte/2017/8302/pdf/Dissertation.pdf

Add MLIB library

```
clear; close all; clc;
mlibfolder = '/home/ivan/Desktop/MLIB';
path(path, mlibfolder);
add_mlib_path;
```

List of models and acquisitions



Model number (IJ) is a combination of reflector type (I) and velocity model (J):

Types of reflector:

1) Flat reflector

2) Plane dipping reflector

3) Point diffractor

4) Sphere with R=1 km

5) Ellipsoid

6) Complex analytical reflector

Types of velocity model:

1) constant: v = v0

2) constant gradient: v = v0 + k*z (z - depth)

3) constant + constant gradient: if (z < z0) : v = v0; else: v = v0 + k*(z-z0)

See all possible models is the table.

Also it is possible to choose one of 5 acquisition geometries:

1) a 2D profile

2) a 2D profile

3) 100 randomly distributed points

4) 3D CMP acquisition

5) 3D ZO acquisition

Set model and acquisition

Note:

Accuracy of traveltime 10e-12

Accuracy of attributes 10e-10

```
model = 61;
acquisition = 2;
```

Get model parameters

```
Get_model_parameters;
```

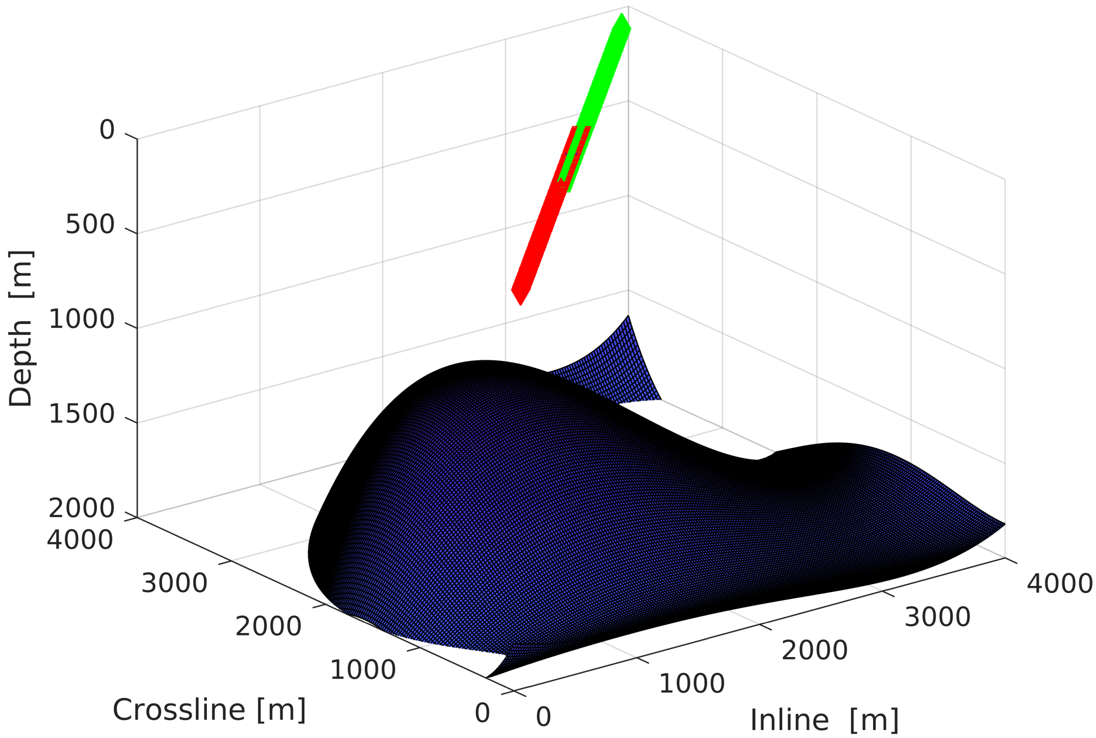
Get acquisition geometry

```
Get_model_acquisition_geometry;
```

Plot acquisition geometry

```
figure(1)
[XX, YY] = meshgrid(G.xx, G.yy);
[ZZ, ind] = Get_model_surface(XX,YY,model);
surf(XX,YY,ZZ);
hold on
plot3(Xs(1,:),Xs(2,:),Xs(3,:), 'rv');
plot3(Xg(1,:),Xg(2,:),Xg(3,:), 'g^');
plot3(X0(1),X0(2),X0(3), 'b*');
axis([G.x0, G.mx, G.y0, G.my, G.z0, G.mz]);
xlabel('Inline  [m]');
```

```
ylabel('Crossline [m]');
zlabel('Depth  [m]');
view(3);
set(gca, 'ZDir', 'reverse')
```



Find stacking parameters

```
[ t0, w3, M3, N3 ] = Get_model_stacking_parameters( X0, model );

CRS_param.x0 = X0;
CRS_param.t0 = t0;
CRS_param.v0 = v0;
CRS_param.w  = w3;
CRS_param.M  = M3;
CRS_param.N  = N3;

save([mlibfolder '/CRS/models/model_' num2str(model) '_CRS_param.mat'], 'CRS_param');
```

either take (x,y) components and find wavefield attributes (reality):

```
w = w3(1:2, 1);
N = N3(1:2, 1:2);
M = M3(1:2, 1:2);
```

```
[ alpha, beta, KNIP, KN ] = my_A2P(v0, w, M, N);
```

or find wavefield attributes and make from them stacking parameters (theory):

```
% [ alpha, beta, KNIP3, KN3 ] = my_A3P(v0, w3, M3, N3);
% KNIP = KNIP3(1:2,1:2);
% KN   = KN3  (1:2,1:2);
% [ w, M, N ] = my_P2A(v0, alpha, beta, KNIP, KN);
```

Exact traveltimes

either download exact traveltimes

```
tti_ex = MLD([mlibfolder '/CRS/models/model_' num2str(model) '_traveltimes_for_acq_' nu
```

or calculation exact traveltimes again

Note: computation of traveltime for model 63 is very time-consuming!!!

```
%tic
%tti_ex = Get_model_exact_traveltime(Xs, Xg, model);
%toc
%save([mlibfolder '/CRS/models/model_' num2str(model) '_traveltimes_for_acq_' num2str(a
```

Traveltime approximations

```
HH = (Xg(1:2, :) - Xs(1:2,:))/2;
MM = (Xg(1:2, :) + Xs(1:2,:))/2;
MM(1,:) = MM(1,:) - X0(1);
MM(2,:) = MM(2,:) - X0(2);

% CRS
tic
tti_crs  = Get_traveltime_3D_CRS (MM, HH, t0, w, M, N);
ctime.crs = toc;
% DSR
tic
tti_dsr  = Get_traveltime_3D_DSR (MM, HH, t0, w, M, N);
ctime.dsr = toc;
% nCRS
tic
tti_ncrs = Get_traveltime_3D_nCRS(MM, HH, t0, w, M, N);
tti_ncrs = real(tti_ncrs);
ctime.ncrs = toc;
% iCRS parabolic
tic
tti_icrs_par_LIA = Get_traveltime_3D_iCRS_par_LIA(MM, HH, t0, w, M, N, 10);
ctime.icrs_par_LIA = toc;
% iCRS 1
```

```
tic
tti_icrs_el_LIA = Get_traveltime_3D_iCRS_el_LIA(MM, HH, t0, v0, w, M, N, 10);
ctime.icrs_el_LIA = toc;
% iCRS 2
tic
tti_icrs_el_TIA = Get_traveltime_3D_iCRS_el_TIA(MM, HH, t0, v0, w, M, N, 10);
ctime.icrs_el_LTA = toc;
```

RMS errors

```
err_rms_crs  = sqrt(sum(((tti_crs  - tti_ex)./tti_ex).^2)/100)*100;
err_rms_dsr  = sqrt(sum(((tti_dsr  - tti_ex)./tti_ex).^2)/100)*100;
err_rms_ncrs = sqrt(sum(((tti_ncrs - tti_ex)./tti_ex).^2)/100)*100;

for iter = 1:10
    err_rms_icrs_par_LIA(iter) = sqrt(sum(((tti_icrs_par_LIA(iter,:) - tti_ex)./tti_ex
    err_rms_icrs_el_LIA(iter)  = sqrt(sum(((tti_icrs_el_LIA(iter,:)  - tti_ex)./tti_ex
    err_rms_icrs_el_TIA(iter)  = sqrt(sum(((tti_icrs_el_TIA(iter,:)  - tti_ex)./tti_ex
end
err = [err_rms_crs, err_rms_dsr, err_rms_ncrs]
```

```
err = 1×3
    1.5239    0.5713    0.0135
```

```

tti_icrs = tti_icrs_el_LIA(iter,:);

texac = reshape(tti_ex,length(hx),length(mx));
tcrs = reshape(tti_crs,length(hx),length(mx));
tncrs = reshape(tti_ncrs,length(hx),length(mx));
tdsr = reshape(tti_dsr,length(hx),length(mx));
ticrs = reshape(tti_icrs,length(hx),length(mx));
```

Compate results

```
figure(2)
subplot(2,2,1)
imagesc( (tcrs - texac)./texac*100);
title('CRS')
caxis([-1 1])
colorbar
subplot(2,2,2)
imagesc( (tdsr - texac)./texac*100);
title('DSR')
caxis([-1 1])
colorbar
subplot(2,2,3)
imagesc( (tncrs - texac)./texac*100);
title('nCRS')
caxis([-1 1])
```

```
colorbar
subplot(2,2,4)
imagesc( (ticrs - texac)./texac*100);
title('iCRS')
caxis([-1 1])
colormap('jet')
colorbar
```