Reflexw laboratory on GPR data processing

Reflexw is a software for 2D and 3D GPR and seismic data processing. It can manage data collected with different configurations: refraction, reflection and tomography.
Open the PDF document containing the software manual and have a look at the Table of Contents and the first manual pages to get an idea about what this software can do and how the user's guide is organized.

- Running the software

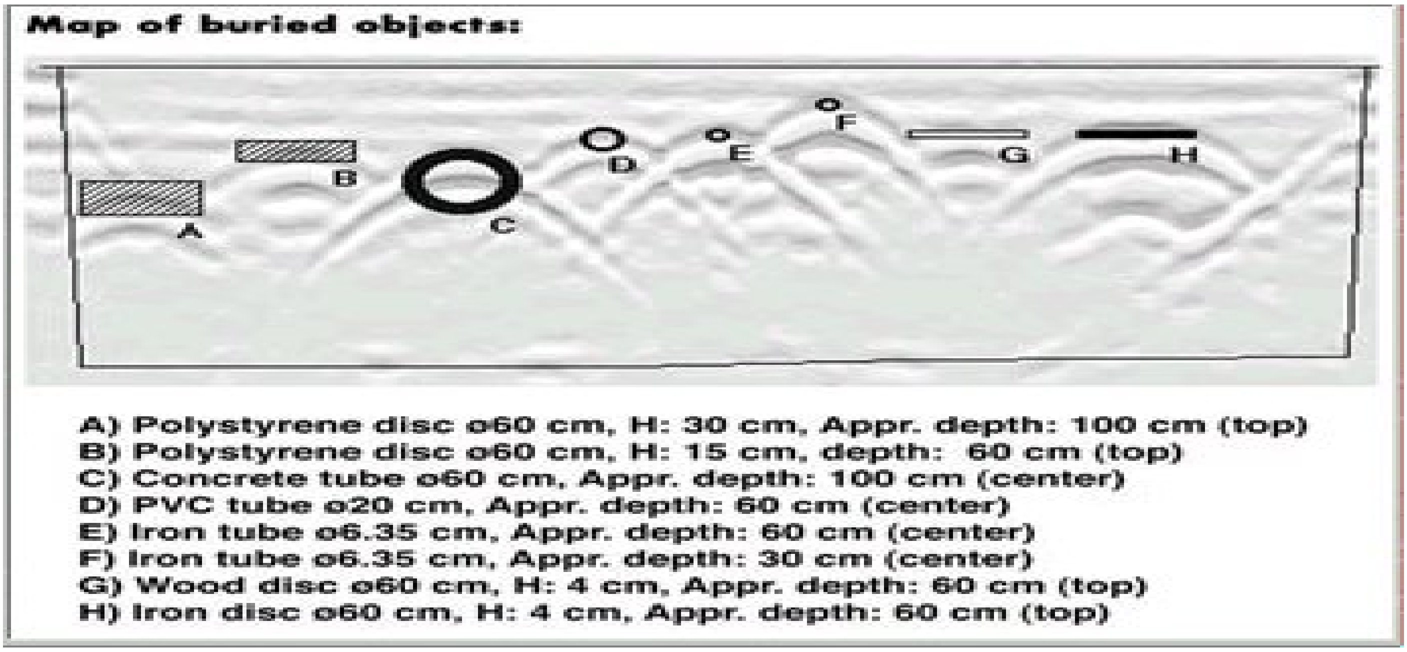
Run the software from the list of the installed programs or from the virtual desktop. The software asks you to create ("new project") or to select ("confirm project") a folder on the local disk or on the virtual machine where you have the write permission. If a new folder is created, the software will also create some subfolders where it will save the data. Have a look at the subfolder structures using Windows Explorer. At the end of the lab session, you can save your work by copying the project folder and subfolders on a USB pendrive.
Be sure to have the required data files: L2-400.rd3 and L2-400.rad.
Have a look at the Help\Content menu and visit some help pages to get an idea about info and helps that are available without opening the full user's guide.

- Data import and display

- Run the 2D-dataanalysis module. Open the Data Import window with the File/import command or with the Import icon.
Have a look at the parameters and options that can be selected. For these GPR data you need to select Meter for the distance measuring unit, Constant offset as Data type, Mala RD3 as input format, new 16 bit integer as output format, Original name as Filename specification, ns for the time measuring unit, no for the Conversion sequence menu.
For details on these parameters click on the Help button at the lower right corner.
Once the Import parameters are set up, click on Convert to Reflex and select the file to be imported (L2-400.rd3).
- The dataimport window will show some info on the selected file such as profile length, trace number, samples per trace, time and space sampling intervals in nanoseconds and meters. After reading these parameters, close the dataimport window and look at the imported data displayed on the main window.
- Open the Plot options window with the Plot\Options command or using the specific icon. Explore and test the available options to become familiar with the graphic features of the program. If necessary, use the help button at the lower right corner.
Compare wigglemode and pointmode to understand the difference between these fundamentals display modes. Use the zoom icons of the main window to reduce the number of traces on display and adjust the plotscale to optimize the visualization. While in wigglemode, test the different wiggle attributes that you can control on the plot options window. While in pointmode, test the Pointmode attributes: explore the available color palettes and play with the commands for controlling the amplitude scale, the amplitude range and the color saturation.
Get familiar with icons and commands available on the top bars of the 2D-dataanalysis window. In particular, play with the zoom icons. And test the Edit file header icon to have access to the time and space info that are saved in the data plus some other info that might be available such as the nominal frequency of the antenna (in MHz) and the Source/Receiver distance, i.e., the TX-RX antenna separation (in meters).
After testing the display options, return to Pointmode and select the optimal parameters (plotscale and color palette) to display this dataset.
The L2-400 profile was collected on a test site by using a Mala GPR system with a 400 MHz antenna. The picture in these notes shows a map of the targets that were buried to create the test site. Compare the map with the data. Note the amplitude and time-space variations among the diffractions generated by the targets. Note the slight misalignment of the background signal at the edges of the image when the antenna moves from undisturbed to disturbed soil or viceversa.

- Time calibration

- The first operation consists of calibrating the time scale so that the time when the transmitting antenna irradiates the radar pulse is moved to time zero. Use the Processing\StaticCorrection menu and select the Move startime function. Select the manual input option. Read the arrival time of the background signal (you can move the mouse on the background signal and read the time value in nanoseconds on the top right X-Y small box). Enter this time in the Move time box (with negative sign so that radar data will be shifted upwards). Before applying the static correction by clicking on the Start button, check the processing label. It is supposed to be 0. This label will be used to identify the name of the processed data file. Click on Start. The result will appear in the lower graphic window. If necessary, repeat the operation till the result is as expected. The processed profile is automatically saved in a new file in the PROCDATA subfolder with a filename extension associated with the Processing label that was selected before clicking on the start button. Reflexw can overwrite on a filename that was already used. If you want to save the result of each processing step on a different file you have to increase the processing label at each step.
Once you are satisfied with the result of the time calibration, the new data can be moved to the upper display window by using the 2->1 button on the top left corner. As a result, the calibrated data becomes the current dataset and the next processing step will be applied to these data rather than to the original dataset.



- Bandpass filter

- Using the View\Profile Histograms command, display the amplitude spectrum of the traces and the average spectrum. Note the band where most of the energy is located to decide the band limits of the passband filter that you will design.
- Open the filtering window using the Processing\1D-Filter function. Test the bandpass filter in the time domain or in the frequency domain. On the right side of the window you can see a single trace and its amplitude spectrum (you can mve to another trace by changing the trace number). Moving the mouse over the spectrum you can read the current position of the mouse. With the small arrows below the spectrum you can zoom on the frequency axis. To enter the filter parameters, you can digit directly within the white boxes or you can select the box and then click with the mouse on the desired filtering position on the spectrum. The corresponding frequency will be automatically entered in the selected box. Increase the processing label to prevent overwriting the current file and click the Start button to apply the filter. Change the parameters and repeat the operation if the result is not satisfactory. When the result is good, close the filtering window and update the upper display window with the filtered data (use the 2->1 button on the top left corner).

- Gain

- Although these data do not need any amplitude recovery because the soil consists of dry sand and signal absorption is very low, it is instructive to explore the gain functions that can be applied when absorption is higher and raw data are apparently showing only the background signal. The software offers several types of gain methods under the Processing\Gain menu. Have a look at the help of the available methods. Test the AGC-gain and the gain function. Explore the parameters and test their effects by applying the gain methods. At the end of these tests, return to the data before the application of any gain and move to the following step.

- Background subtraction

- Select the Background Removal function from the Processing\2D-Filter menu. Increase the processing label and test the function trying to optimize the parameters that you can control from the filter setup window. Specifically, the option distance range might be useful to optimize the background removal within the area of interest, i.e., the area of the buried targets. Save the best result and then increase the processing label to test the Subtracting Average function as an alternative to the Background removal function. In this case you have too optimize the result by controlling the number of traces of the moving average filter. Save the best result. Compare the two results using the upper and lower display windows. To open the data on the upper and lower window respectively, you can use the File|Open|ProcData and the File|OpenSecondLine|ProcData from the File menu.

After the comparison, open again the data before the background subtraction to test another approach for this operation.
- Select the FK filter from the Processing menu. On the small window that will appear, select fk-filter and generate the fk-spectrum by clicking on the proper button. Have a look at the FK spectrum. Observe the x and y axis and the frequency axis orientation. You can optimize the display parameters by zooming on the spectrum, by changing the colorpalette and by controlling the amplitude range from the plot-options window. Get familiar with the FK filter by testing for example a filter that removes all the positive or the negative wavenumbers (options neg kx or pos kx). Be sure to select bandpass or notchfilter depending on what you are designing, i.e., the mask of the spectrum area that you want to preserve or remove. For each test, look at the result and try to understand what is happening. After these tests, select the manual option and try to design the mask of the background removal filter directly on the FK spectrum (click with the mouse on the selected corners of the mask). Apply the filter and repeat till you are satisfied with the result. Finally, compare this result with the best result obtained with the previous methods.

- Velocity analysis

- Activate the functions for interactive velocity analysis by selecting the Analysis\Velocity adaptation function or by clicking on the corresponding icon (where you see a small hyperbola and a V letter). Read the help page of this function to understand the available options. Activate the S/R-dist option. Click on the velocity box so that it becomes light blue meaning that it is active. Perform a diffraction adaptation analysis by moving the mouse over the different diffractions without clicking on the radar image and use the > and < keys on your keyboard to adjust the velocity to fit the hyperbolas. Try to find a unique velocity for the whole profile (the soil of the test site is homogeneous and a costant velocity is expected). For the larger targets, where you see a distorted diffraction with a flatted upper part, you can explore the effect of the radius option. Memorize the velocity that generates the best hyperbola fit for all the diffractions.

- Migration

- Once the velocity is known, data can be migrated and/or time-depth converted. Migration is needed except when the image only shows horizontal reflectors. Open the migration window by using the Processing\Migration function. Select the Diffraction stack option to test the Diffraction Summation method. Read the help of the function to get familiar with the options and the parameters. Apply migration with the velocity estimated at the previous step. Optimize the parameters to get the best result. In case of over or under migration, change the velocity to improve the focusing of the diffracions.
- Update the current dataset with the migrated data (use the 2->1 button on the top left corner).
- Select the Processing\Complex TraceAnalysis function and extract the envelope of the migrated traces. Choose the best colorbar to display the data envelope and optimize the amplitude range (suggestion: envelope amplitudes are positive). Activate the option View\Colorbars to display the colorbar on the right side of the display.

- Time-to-depth conversion

- Activate the DepthAxis option in the plot-options window and enter the velocity that was used to migrate the data. As a result, a depth axis will appear on the right side of the radar image. Use the zoom function and play with the size of the 2D-data analysis window to obtain an image with the same scale for the x and z axes. Activate the graphic option Grid and compare the depth of the migrated targets with the actual depth as reported in the test site map. If time calibration and velocity analysis were properly performed a good match (within the limits of the experiment resolution) is expected between the depths indicated in the test site map and the radar image results. Note that the experiment resolution is not enough to estimate the correct size of the targets, especially the smaller ones. Finally, compare the intensity of the target images with the target materials listed in the site map to get an idea of radar sensitivity versus target material.

- 3D data processing (Venice, 2GHz)

- Run the Reflexw software and create a new project with a new name (e.g., GPR3D).
- Be sure to have the data files named LZZ100**.dt from LZZ10011.dt to LZZ10050.dt collected on the floor of an old palace in Venice with a 2GHz antenna as shown in the picture. With the help of a grooved pad the antenna was moved along many parallel profiles to produce a 3D dataset. The objective of the radar investigation is to detect horizontal metal elements connecting the timber beams to the stone walls.

- Run the module 3D-DataInterpretation. Select the File\Import\2D lines command and set up the parameters as follows: Data type = constant offset, Input format = IDS, Filename specification = manual input (you need to enter a name for the new 3D file that will be created by combining the parallel profiles, e.g., "Venice"), Conversion sequence = combine lines, Line distance = 0.016 (this is the interdistance between the parallel profiles in meter). Be sure to have the options "control format" and "read trace incr." activated. Click on the Convert to Reflex button and select all the 40 files that must be combined.
- Use the File\Open3Dfile\rawdata command or the corresponding icon to read and display the 3D file created with the import operation. A new small window will appear where you need to select the option "no". The new data will show up and a new set of graphic options will appear for controlling the display of the 3D data volume.
- Use the File\Edit file header command or the corresponding icon to read the acquisition parameters such as the time and space sampling invervals, the number of traces per profile and the number of samples per trace. You will see that the nominal frequency of the antenna and the TX – RX separation distance are missing or are not corret. Enter the nominal frequency (2000 MHz) and the TX-RX distance (0.06m) and click on SAVE to update the file header.
- Test the options available for the display of the data volume. Start by selecting the Scroll option to explore the volume along vertical X or Y cuts or along horizontal slices. Use the buttons below the image to control the scrolling. Explore the options that appears on the left side of the image by selecting the Options button.

Select the 3D-cube option and click on Plot on the left side menu to refresh the display. A 3D display will be activated. Adjust the magnification and the X and Y scaling to display the volume as a 3D box with proper size. Rotate the box by using the mouse or by using the sliders available on the left side menu. Try to cut the volume along all the directions simultaneously and scroll the cuts with the scroll button and options of the left side menu. Test also the full display mode (available on the left side menu) and get familiar with its control functions. Finally, test the Indiv. cut option to cut the volume along dipping planes.

- Select the Processing command and explore the options (envelope, absolute values, ...).
- Reflexw assumes that the processing of 3D data is performed with the same functions that are applied to 2D data, apart a few exceptions. These data need to be processed by applying at least the following operations: time calibration, bandpass filtering, background subtraction, velocity analysis, migration, time-depth conversion and 3D visualization for final interpretation of the results. Before closing the 3D-Data Interpretation module, explore again the data volume to decide whether these data will need a 2D or a 3D migration to best focus the metal elements.
- Close the 3D-DataInterpretation module and run the 2D-DataAnalysis module. Use the File\Open\rawdata command or the corresponding icon to load the 3D data file. The data will be displayed as a single file that actually consists of a sequence of 40 profiles plotted one after the other.
- Apply the most appropriate processing sequence in order to detect the metal elements. Be particularly careful when performing the velocity analysis. The floor consists of the same material everywhere so that a constant velocity is expected. Is it possible to find a good velocity for the whole data volume. If not, why? Use the best velocity that you obtained to migrate the data with the 2D diffraction stack method or the 3D-fk method. Compare the results obtained with the two methods and analyse the differences. Are the results consistent with your expectations?
- Display the migrated volume with the tools of the 3D-DataInterpretation module. Activate the DepthAxis option or the Time/Depth conversion (depending on the display tool that you are using). Choose the best graphic solutions in order to enhance the shape and the extension of the metal elements detected by the radar survey. Play also with the View\Fast Data Cube Display tool to generate and rotate a 3D plot of the metal targets. Discuss the results with the instructor.