Non-Invasive Tree Root Inspection with Stepped Frequency Wave GPR

Many countries around the world are planting more trees in urban areas for aesthetic, public health and environmental reasons, however this increases the risk of injury and death due to falling trees. Especially for large trees, it is very important to inspect the full system of tree roots to detect any root damages which can lead to tree death or collapse.

Ideally, roots are monitored non-invasively to minimize time and labour expenses, and to reduce the chance of damage being done to the tree root structure and soil environment.

Challenge

Traditionally, several methods have been utilized to evaluate tree root systems. These include taking photographs with a miniature camera placed inside a transparent tube (minirhizotron) that is inserted into the soil; high-pressure air shovels and physical excavation. These methods are time-consuming, labour-intensive and potentially damaging to the tree root structure and the soil environment. They are also unsuitable for continuous monitoring of roots over long periods of times.

Ground Penetrating Radar (GPR) is a practical, effective and suitable NDT method for large-scale root inspection. Its resolution is sufficient to resolve coarse roots with diameters of 2-3cm and above.

The goal of this study was to conduct a GPR investigation of two trees to identify underground tree roots structures (especially the anchorage roots; diameters above 2 to 3cm) and to investigate the soil conditions. For both trees, the area of investigation was a circle of diameter 6-7m. In the past, difficulties with GPR set-up and low-quality data made this application very difficult. It was previously challenging to collect and view data on site and several spurious reflections were visible.

Solution

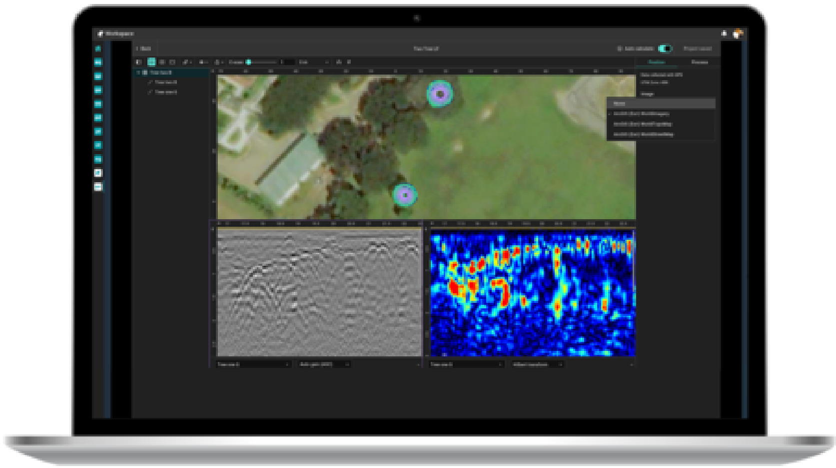
Proceq GS8000 is a subsurface mapping system which uses Stepped Frequency Continuous Wave (SFCW) GPR technology. Advantages of SFCW include improved signal-to-noise ratio, enhanced dynamic range and ultrawide bandwidth (for GS8000 this is 40MHz to 3400MHz). Proceq GS8000 has an in-built GNSS receiver, MA8000, for position data collection.

GS8000 is a pushcart system with 4 wheels, the GPR antenna and the integrated GNSS rover, MA8000. The GS8000 was pushed around the tree in concentric circles of reducing diameter. The MA8000 with RTK correction service collected geographical position data with centimeter accuracy continuously throughout the scan. GPR data was collected in real-time through the iPad app, “GS 2”. The iPad connects wirelessly to the GS8000 pushcart. Bandpass filtering, background noise removal and dielectric calibration were done in real time on the iPad itself.

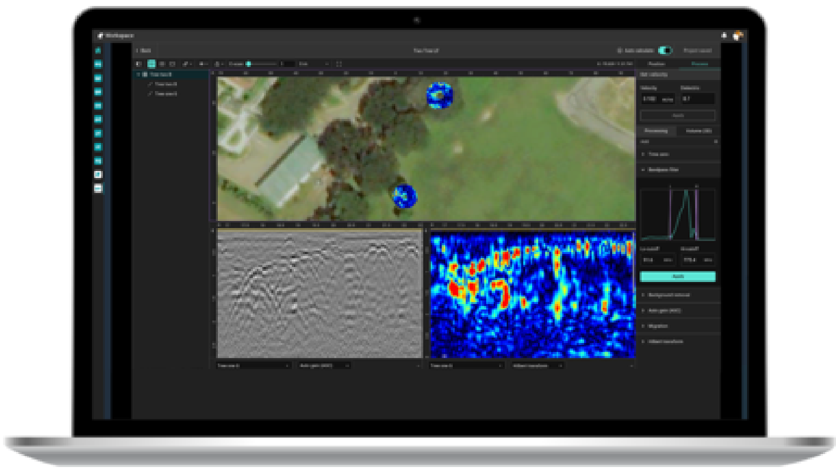
The finished data was also instantly synced to the online platform, Workspace, for viewing on an internet browser at any location. Since the GPR data was saved together with geographical position information, the results could be superimposed on Google Earth for a very clear understanding of exactly where the GPR scan was performed.

Results and Data Processing Procedures

Directly in the field using the iPad or later going back to the office, we could perform the data post-processing right away. All that was required was to upload the two individual GS8000 data to this web-based GPR Insights.

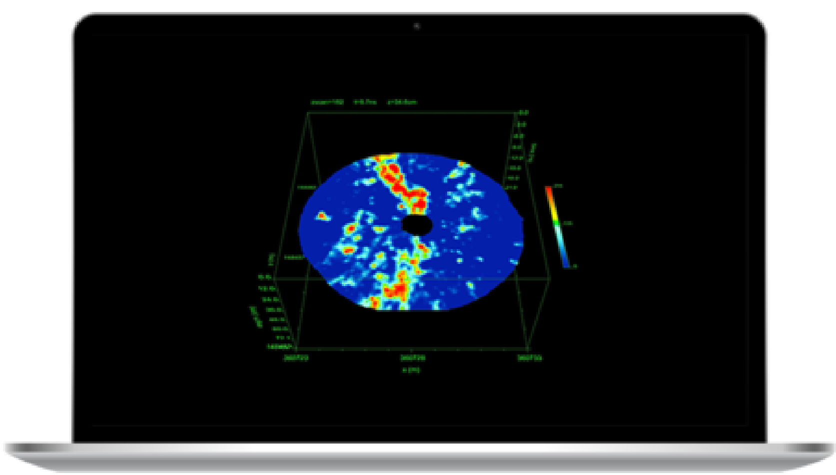


With its automatically processing and cloud computing power, we may just need to wait for 1 or 2 minutes, 2D radargram and 3D slice view were automatically generated.



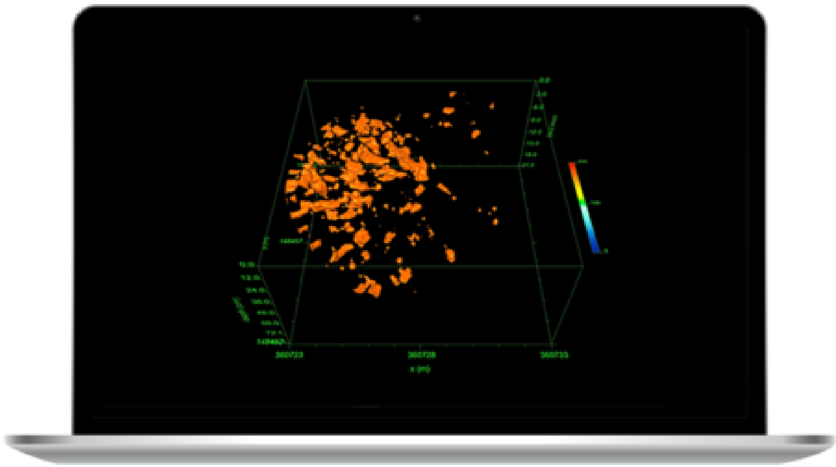
Since the data was collected with centimeter level accuracy GNSS, depth slice results could be superimposed on a geo-map. We can easily understand the distribution of tree root system within the measurement coverage. By pinpoint on the geo position we can locate what we want at actual location.

The GPR data was also downloaded onto a PC and processed using GPR-Slice v7.MT software. The following steps were conducted in GPR-SLICE: 1D batch gain and 2D filtering steps, auto gain correction, migrations and other 2D corrections.



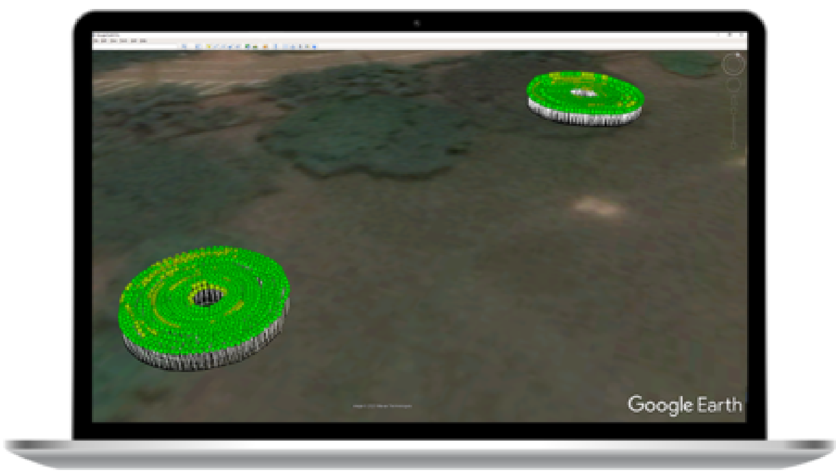
2D results of one tree displayed in GPR-SLICE. A depth or time-slice view is shown. This is a cross-section parallel to the ground surface.

The processed 2D image was displayed as a continuous line. The GNSS data was then automatically integrated with the GPR data to get a correct representation of concentric circles around the trees. A 3D cylinder of data is obtained, with a hole through the middle representing the tree trunk. The data was sliced and gridded to obtain 40 profiles. It is possible to easily determine the exact location of the roots and any anomalies. For example, the 3D image clearly shows the tree roots distributed heavily to one side, from a depth of approximately 12cm till 60cm which is not ideal.



3D results displayed in GPR-SLICE. The 3D orange shapes are areas of higher reflection amplitude and they represent the architectures of tree roots, in particular the anchorage roots.

Note that 3D visualization was done using OpenGL, which also supports Google Earth background, so that interesting GPR results can be overlaid on the respective Google Earth image.



GNSS positions around the two trees, overlaid on Google Earth image. Green colour indicates an excellent GNSS correction status and yellow indicates a less good status.

Conclusion

Proceq GS8000 has been proven to be an ideal candidate for non-invasive, reliable inspection of tree roots. It is quick, safe for the operator and does not damage the tree roots or soil. If necessary, it can be repeated at frequent intervals to closely monitor tree roots. The use of GNSS receiver, MA8000, and post-processing software, GPR Insights and GPR-SLICE make data interpretation much easier and quicker.

From this study, we strongly suggest that pairing high-density geophysical data with crystal clear SFCW GPR data is critical to interrogate a complex tree root structure.

Learn more about the GS8000 subsurface mapping system on our Tech Hub.