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A Research in Progress: Ground Penetrating Radar (GPR) for Tree Trunk Assessment

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Background

In the city-state of Singapore, trees are abundantly planted along roadsides, housing estates, parks, nature reserves and even on top of buildings, forming a pervasive network of greenery.

Trees add colour and contrast to our local environment, softening the hard lines of concrete buildings and infrastructure. Besides the aesthetics, they also contribute significant environmental benefits such as improving air quality, and mitigating the greenhouse effect. Trees, particularly mature ones, form an integral part in balancing and maintaining our ecosystem. In addition, they bring about psychosocial benefits, including enhancing our quality of life.

A number of technologies have been employed in the care and preservation of trees. In this Research Technical Note (RTN), we will focus on one particular technology that is often used in tree root assessment, the **Ground Penetrating Radar (GPR)**.

Fig. 1 Tree trunk scan on a healthy tree specimen

Working Principles of the Ground Penetrating Radar (GPR)

The GPR has been adopted across different fields since its inception (geology, archaeology, forensic). In recent years, its accuracy, non-invasive and non-destructive potential have been widely accepted, and as a result, GPR has been extensively used in forestry based applications.

This geophysical, close-range remote sensing technology uses high frequency electromagnetic (EM) pulses to obtain cross-sectional images of underground features. The antenna emits EM pulses, which operates in the microwave range (ultra-high and very high frequencies), penetrates deep into the ground, and is reflected off organic structures like roots (Figure 2) or man-made objects, like pipes.

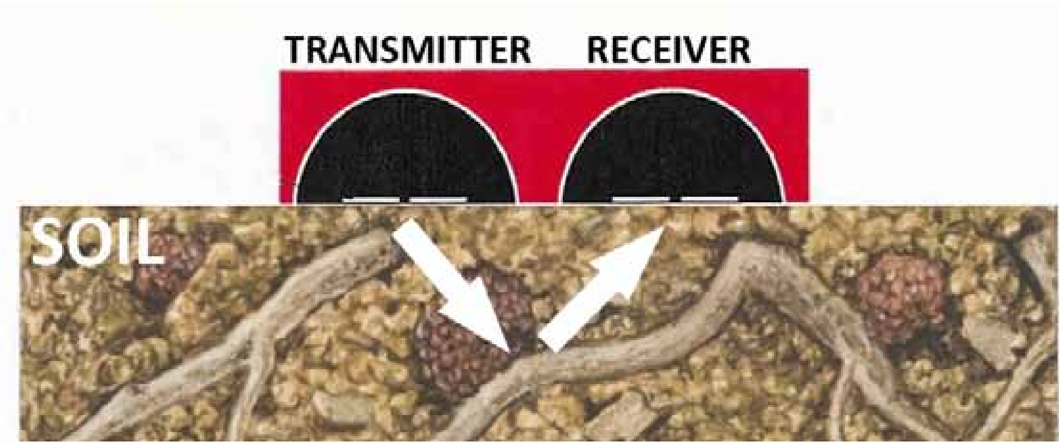

Fig. 2 Illustration on the basic principles of the GPR

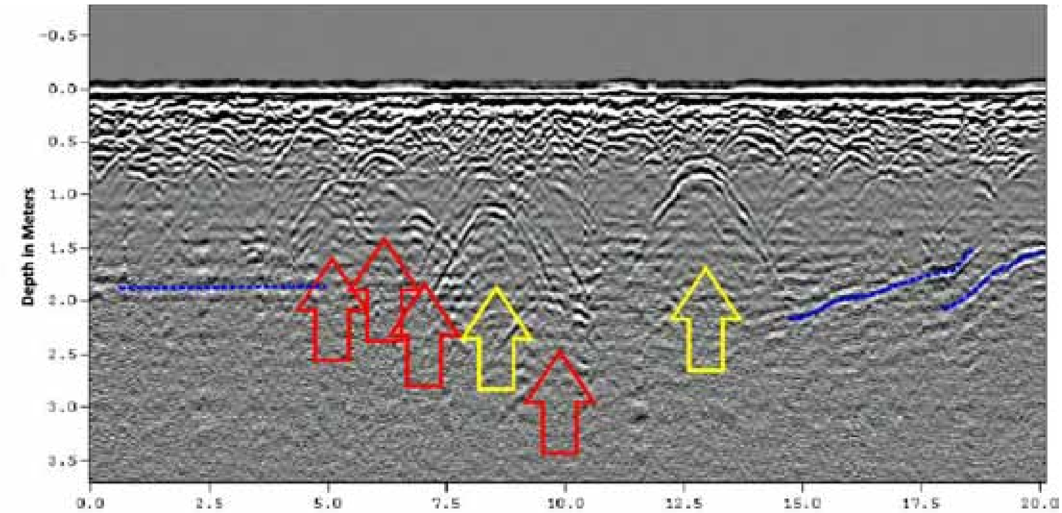

Fig. 3 Presence of hyperboles (subsurface structures) in 2D

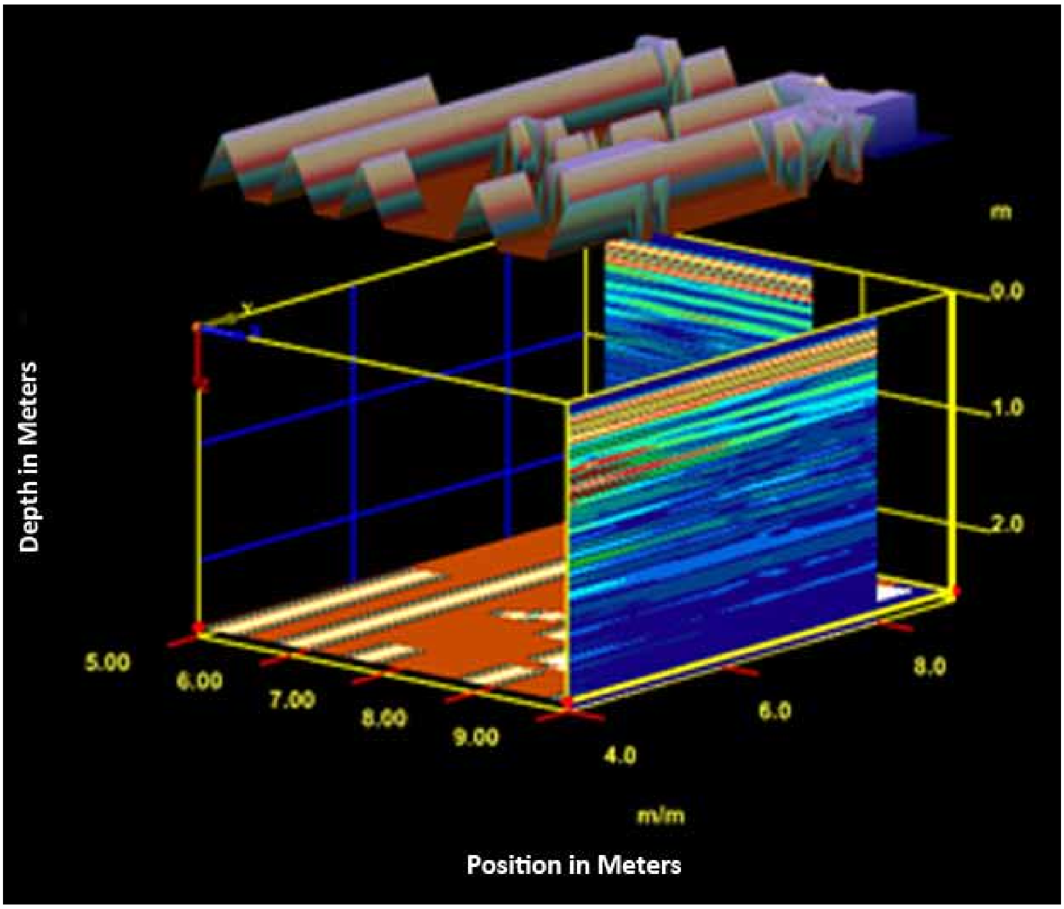

Fig. 4 Presence of anomalies (pipes in this instance) in 3D

The data is then captured and amplified by a computer with the appropriate software, which represents it in real time 2D and 3D formats (**Fig. 3 and 4**).

Here are some examples of forestry based applications of the GPR.

1. Map shallow bedrock, subsoil stratigraphy and estimate shallow water table depths.
2. Map tree root systems where it has been shown to detect medium and large sized roots, as well as clusters of small roots.
3. Analyse tree trunks and dry timber to evaluate different radar signals and observe differences in electromagnetic properties.

Fig. 5 Conducting a root scan under a concrete path

Current GPR Application in NParks

As roots grow in highly elusive environments; the GPR is a sound technology to detect conflicts between roots and infrastructure (**Fig. 5**).

The non-destructive and non-invasive potential of the technology allows for multiple surveys, unlike conventional assessment methods like excavation that would otherwise cause harm to trees.

For the past six years, NParks has implemented this technology for tree root assessment in the following areas.

1. Determine root location and density at construction sites.
2. Isolate foundation damage caused by invasive tree roots.
3. Evaluate and determine where to carry out trenching activities.
4. Prevention of root damage in sidewalk or kerb upgrading.
5. Assessment of tree stability through determination of root density and depth.

Application of GPR Looking for Internal Defects in Tree Trunk Inspection

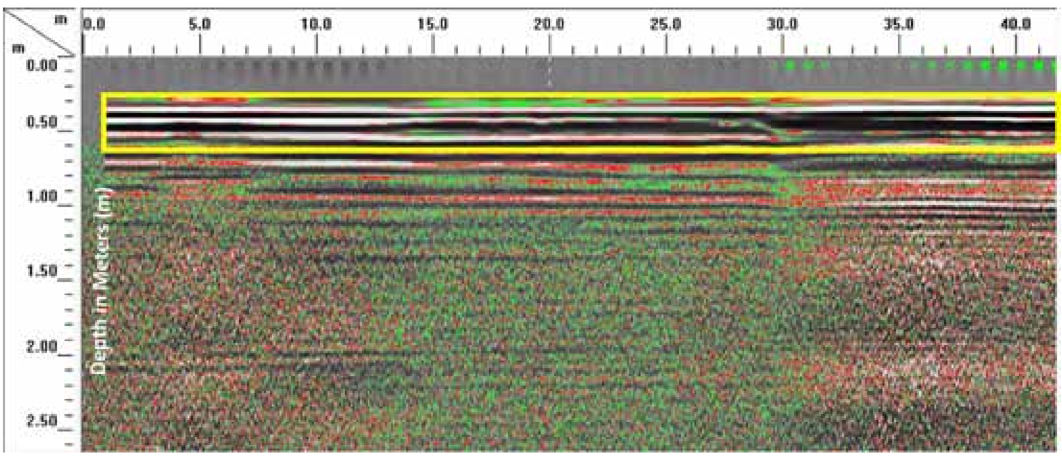

Fig. 6 GPR data of healthy tree showing voids of internal reflections

Application of GPR on tree trunk assessment is mainly to detect the presence of internal defects within the trunk. An example of such internal defects is wood decay. Wood decay is a biological process whereby cellulose and lignin, two organic compounds, are converted to carbon dioxide, water and energy.

Although it is a natural process in the nutrient cycle, wood decay reduces the wood strength and is a risk to people and property in surrounding urban environments. The causal agents of wood decay in the urban environments are often the macrofungi seen as fruiting bodies on trees, and they are often introduced through wounds due to pruning, grass cutting and construction activities. Decay results in changes in wood trunk moisture content and wood density. The GPR makes use of these changes to hone in and detect hollow and decayed wood in trees.

GPR data is collected by moving the antenna around the circumference of the tree (at several known heights), thereafter, the linear 2D data will be transformed into polar coordinates for comparison against the tree section through a computer and software.

Recent findings generated from the GPR data collected have shown that healthy trees are usually void of internal reflections, but may in some cases show weak parallel bands (**Fig. 6**). However, sections of hollowness or decay will be correlated with cluttered reflections, peaks, discontinuities, and depressions. This is likely to be attributed to moisture and loss of wood density close to the heart wood or sap wood interface.

Comparisons with destructive sampling were made and concurrence was found between radar assessment of standing trees, and destructive sampling, where healthy trunk was found to correlate with decreased electric properties. Further research into this technique will need to be carried to further substantiate these findings.

Potential Challenges with the GPR for Trunk Surveys

The main challenges associated with the GPR to evaluate defects is the difficulty in coupling the antenna to the curved bark surface (**Fig. 7**), as well as, the interpretation of complex data.

Fig. 7 Difficulty in scanning buttressed roots

Variations between species, trunk size, and moisture gradients in relation to heart wood development and environmental factors tend to complicate data interpretation even further.

Presently, it is also limited in its ability to map out the geometry of the tree trunk, and does not detect the amount of decay. However, it is noteworthy that these challenges may be overcome as research in this field is rapidly advancing, and applications of GPR designed specifically for trunk analysis maybe commercially available soon.

Alternative for Tree Trunk Surveys

PiCUS Sonic Tomograph is another non-invasive instrument to detect decay and cavities in living trees. It works on the principle that sound waves passing through decay move more slowly than sound waves traversing through solid wood. A two-dimensional image of the cross-section of the tree (tomograph) is then formed by sending sound waves from a number of points around a tree trunk to the measuring points, where the relative speed of the sound is calculated.

The GPR, like the PiCUS, is also able to detect internal decay, resulting from changes in moisture content or wood density. The GPR uses high frequency electromagnetic pulses that are transmitted into the ground (or wood) and the reflected signals are returned to the receiver and stored on digital media. The computer measures the time taken for a pulse to travel to and from the target which indicates its depth and location. Essentially, the difference between the two techniques is in the mode of signal transmission, data presentation and interpretation.

Both techniques have its merits and this technical sharing does not suggest that one tool is better than the other. In fact, in some situations, it can be a complimentary technique and a combination of both may be used to validate findings.