GROUND PENETRATING RADAR: A SOLUTION TO THE ELUSIVE UNDERGROUND TREE ROOT SYSTEM

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In many cities, trees are often planted along roadsides and other infrastructure to beautify the environment and provide shade. As a result, there are incidences of damage to infrastructures caused by trees with extensive tree root systems.

Thanks to advances in technology, we can now locate tree roots and map root depths using Ground Penetrating Radar know-how (GRP). This technique is especially ideal for an urban environment as it allows for in-situ imaging of tree root systems, without disrupting the tree roots.

PRINCIPLE BEHIND GPR TECHNOLOGY

GPR has been used for a number of years in construction and mining applications, environmental audits and site assessments, as well as geological and archaeological studies. Providing a continuous profile of the subsurface, GPR has been helpful in locating underground utilities, storage tanks, old foundations, abandoned mine shafts and sinkholes. The GPR works on the principle that high frequency electromagnetic waves are reflected off objects having different electrical properties compared to the surrounding subsurface material. The returning signals from the boundaries of these objects are detected with an antenna, processed and displayed in real-time to provide a profile view of the electrical structure of the subsurface.

THE MECHANISM

Over time, several easy-to-use cart-based GPR systems have evolved. When selecting a GPR system, two important aspects should be taken into consideration: (1) will the GPR system work in the region to be studied and (2) will the system meet the current and intended needs of the user(s). Considerations for the first criteria should include two electrical parameters that govern how well the GPR system will function. The electrical conductivity and electrical permittivity (dielectric constant) controls the amount of signal absorption and depth of exploration. Research in Singapore suggests that the best subsurface environment for the GPR to function optimally is in soils with low-conductivity and low-permittivity values, i.e. soils with low moisture content.

The physics of transmitting electromagnetic energy into the ground and the subsurface is similar for all GPR systems but the equipment requires a great deal of calibration and fine-tuning. The original system was tailored for locating utilities in the form of regular-shaped objects rather than tree roots. Therefore, the expectation with respect to exploration depths and/or target resolution for tree root scans should be duly managed.

Despite its limitation, the GPR has its advantages in that it is non-destructive, and causes no damage to the areas surveyed. However, it is important to note that the GPR works on the principle of relativity: it detects changing conditions from the surface down but is unable to identify the precise nature of the materials surveyed. In some cases, it may be necessary to supplement the GPR data with absolute data, which can be derived using methods like air spading. The output from a GPR survey should not be confused with that of a vertical section drawing. The returning signals, which come in the form of hyperbolas, are only likely to make sense to the trained eye.

The Centre for Urban Greenery and Ecology has embarked on research concerning the application of GPR in detecting tree root systems in Singapore. The results have shown that GPR does not work well in clay soils, especially under waterlogged or saline conditions. Such soils are relatively ionised and cause reduction in returning signals. Waterlogged clayey soils attenuate the signals to the greatest extent and significantly limit the effective depth of investigation. While a lower frequency antenna can be used to enable greater penetration of the signal, this will be at the expense of near surface and lateral resolution. Therefore, it is essential to identify the prevailing soil conditions and the level of water table before conducting a GPR survey.

Positional information must also be taken into account in GPR surveys. A grid of parallel lines must be marked out around the trees before each survey in order to achieve both two-dimensional and three-dimensional reconstructions of the root system. In cases where the position of the target is known, the radar should cross the longitudinal axis of its target. Where the position of the target is unknown, the survey should be carried out in two perpendicular directions. Following these rules will give better results. It is also important to maintain close contact between the ground surface and the antenna and to pace the steps (slow movements recommended) the user(s) make along the grid lines, to prevent the introduction of noise into the data. Where possible, obstructions in the form of rocks and other vegetation should be removed from the survey grid. Large antennas can cope with conditions that smaller ones cannot but most antennas should be able

to cope with various surface conditions so it is not a question of which is better but rather, which is most suitable.

THE APPLICATIONS
GPR can be used for locating and assessing tree root spread and position under different surfaces like tarmac, concrete and grass. It acts as a "virtual excavator", providing a rapid, non-invasive analysis of the roots below the surface. Imaging of roots is useful as it facilitates the subsequent planting of trees or the installation of utilities in built-up areas. The technology also allows for the identification of roots proliferation in relation to drains or other services and can avoid infrastructural development from encroaching onto green spaces.

CONCLUSIONS
GPR surveys provide a useful approach to root investigation, in describing both the shape and behaviour of the roots in the subsoil. To achieve better results, it is necessary to alter the technical parameters such as the dielectric constant, maximising the potential of post-processing software, like the RADAN, to generate better quality, higher resolution outputs. Further studies will focus on two directions: (1) the improvement of standard field procedures and (2) correlating the recovered resistivity distribution with root volumes.

TOP Ground Penetration Radar Survey over a rectangular grid of evenly-spaced parallel lines.