Detection of plant root orientation using ground-penetrating radar

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With the function of water absorption, nutrient transportation and storage, root system plays a significant role in plant ecosystem [1]. Nevertheless, subject to the inconvenience of underground investigation, surveys on root system under natural circumstance have lagged far behind those on the aboveground part. Due to its in situ and non-destructive nature, ground-penetrating radar (GPR) has recently been applied for field investigation of plant roots, such as automatic three-dimensional reconstruction of root system and quantitative inversion of root parameters. It is the discrepancy between the roots and surrounding soils that creates a dielectric constant contrast, forming clear hyperbolic reflections on the GPR radargram. The intensity and shape of the reflecting signals from roots are substantially affected by the root orientation and as well the relative geometry between the root in subsurface and GPR survey direction on ground surface. However, no previous study has utilized the information on intensity and shape of root’ s GPR reflection to map its orientation, which is crucial in interpreting radargram and rebuilding three-dimensional root system architecture. In this study, a mathematical formulation of hyperbolic reflection formed by a single root was first deduced based on principles of electromagnetic wave propagation and the relationship between the shape of the GPR signals and root orientation was analyzed. Then using such formulation, curve fitting was conducted on both simulated and field collected dataset by GPR. Information on the horizontal orientation and vertical inclination of a single root was acquired according to the formulation coefficient retrievals. Based on this, a method for retrieving the horizontal orientation and vertical inclination angle of a single root from a given GPR image was proposed. This method took advantage of mathematical modeling with curve fitting in root orientation estimation. Meanwhile, conditions for this method application and factors impacting on the extraction of root orientation information were analyzed. The results indicated fairly precise root orientation estimation. The proposed method has extended the application of GPR in root investigation, advancing the frontier of non-invasive root system architecture mapping.

Keywords: ground-penetrating radar, root orientation, curve fitting

