

Diagnosing Acute Oak Decline Using Ground Penetrating Radar


¹Iraklis Giannakis, ¹Amir M. Alani, ¹Livia Lantini, ²Dale Mortimer and ¹Fabio Tosti

¹*School of Computing and Engineering, University of West London (UWL), St Mary's Road, Ealing, London W5 5RF, UK*

²*Tree Service, London Borough of Ealing, Perceval House, 14-16 Uxbridge Road, Ealing W5 2HL, London, UK*

Emerging infectious diseases (EIDs) of trees have rapidly increase during the last 20 years due to modern socio-economic factors such as global timber trade and international travelling [1], [2]. Currently, the most dominant EIDs affecting the European forests are the ash dieback [1], the *Xylella Fastidiosa* [3] and the acute oak decline (AOD) [4]. AOD is a bacterial infection that can lead to tree mortality within 3-5 years [4] and has rapidly spread in the United Kingdom since its first outbreak in 2012 [5].

Monitoring modern EIDs such as AOD requires new forestry approaches and modern detection schemes [2]. To this effect, ground penetrating radar (GPR) has been suggested as a diagnostic tool against AOD [5]. GPR is a non-destructive method that has the potential to detect tree-decay in a non-intrusive manner [5]. Commercial common-offset (CO) GPR systems are easily accessible and trivially deployable in the field. In addition, CO-GPR requires minimum computational and operational requirements. The above makes CO-GPR an appealing detection method for AOD especially for large-scale forestry applications [5].

The most mainstream symptom of AOD is the formation of liquid-filled chambers parallel to the main axis of the trunk [4]. The liquid-filled chambers occur predominantly between the outer sapwood and the bark. In late stages of AOD, the decay extent to the outer bark creating visible  patches with a characteristic black colour [4].

In the current paper, we examine the capabilities of a high frequency CO-GPR system in detecting tree-decay associated with AOD, i.e. in detecting small shallow liquid-chambers within the trunk. In this context, a detection framework based on measurements collected around the circumference of the trunk is proposed [5]. First, data are accurately positioned using an arc-length parameterisation [5]. The ringing noise and the unwanted clutter are removed effectively using the singular value decomposition (SVD) method [5]. Subsequently, a reverse-time migration is applied to the filtered data in order to collapse the hyperbolas to their origins. The finite difference time-domain (FDTD) method is used to back-propagate the received reflections. The velocity of the medium is assumed to be homogenous and the permittivity is evaluated using auto-focusing criteria [6]. Lastly, the migrated images are smoothed using a Gaussian blur filter and subsequently squared to further enhance the resulting signal. The viability of the suggested scheme has been proven successfully with numerical, laboratory and on-site tests, indicating that GPR is a commercially appealing

methodology for diagnosing early symptoms of AOD.

Acknowledgments

This paper is dedicated to the memory of Jonathan West; a friend, a colleague, a forester, a conservationist and an environmentalist, who died following an accident in the woodland that he loved.

The authors would like to express their sincere thanks and gratitude to the following trusts, charities, organisations and individuals for their generosity in supporting this project: Lord Faringdon Charitable Trust, The Schroder Foundation, Cazenove Charitable Trust, Ernest Cook Trust, Sir Henry Keswick, Ian Bond, P. F. Charitable Trust, Prospect Investment Management Limited, The Adrian Swire Charitable Trust, The John Swire 1989 Charitable Trust, The Sackler Trust, The Tanlaw Foundation, and The Wyfold Charitable Trust.

References

- [1] A. Broome, D. Ray, R. Mitchell and R. Hammer, [Responing to ash dieback \(Hymenoscyphus fraxineus\) in the UK: woodland composition and replacement tree species](#), [Forestry, An International Journal of Forest Research](#), vol. 92, pp. 108-119, 2019.
- [2] A. Santini, L. Ghelardini, C. De Pace, [] and J. Stenlid, [Biogeographical patterns and determinants of invasion by forest pathogens in Europe](#), [New Phytologist](#), vol. 197, pp. 238-250, 2012.
- [3] J. D. Janse and A. Obradovic, [Xylella Fastidiosa: its biology, diagnosis, control and risks](#), [Journal of Plant Pathology](#), vol. 92, pp. S1.35-S1.48, 2010.
- [4] N. Brown, D. J. G. Inward, M. Jeger and S. Denman, [A review of Agrilus biguttatus in UK forests and its relationship with acute oak decline](#), [Forestry](#), vol.0, pp. 1-1, 2014.
- [5] I. Giannakis, F. Tosti, L. Lantini and A. M. Alani, [Health Monitoring of Tree Trunks Using Ground Penetrating Radar](#), [IEEE Transactions on Geoscience and Remote Sensing](#), Early Access.
- [6] I. Giannakis, F. Tosti, L. Lantini and A. M. Alani, [Diagnosing Emerging Infectious Diseases of Trees Using Ground Penetrating Radar](#), [IEEE Transactions on Geoscience and Remote Sensing](#), Under Review.

Keywords: tree health monitoring; emerging infectious diseases (EIDs); acute oak decline (AOD); ground penetrating radar (GPR); finite difference time-domain (FDTD) simulations