PHOTOGRAMMETRIC NEWS: Doctoral Dissertation

Mr. Jussi Juola defended his doctoral dissertation on the 10th of November 2023 at the Aalto University School of Engineering, Finland. Dr. Michael Förster, Technical University of Berlin, Germany, appeared as opponent. The Supervisor was Professor Miina Rautiainen, Aalto University, School of Engineering, Finland. The title of the thesis was “Hyperspectral imaging of tree stems”. Video summary of the dissertation:
https://www.youtube.com/watch?v=Mx-3tcKjNxk

Abstract of the thesis

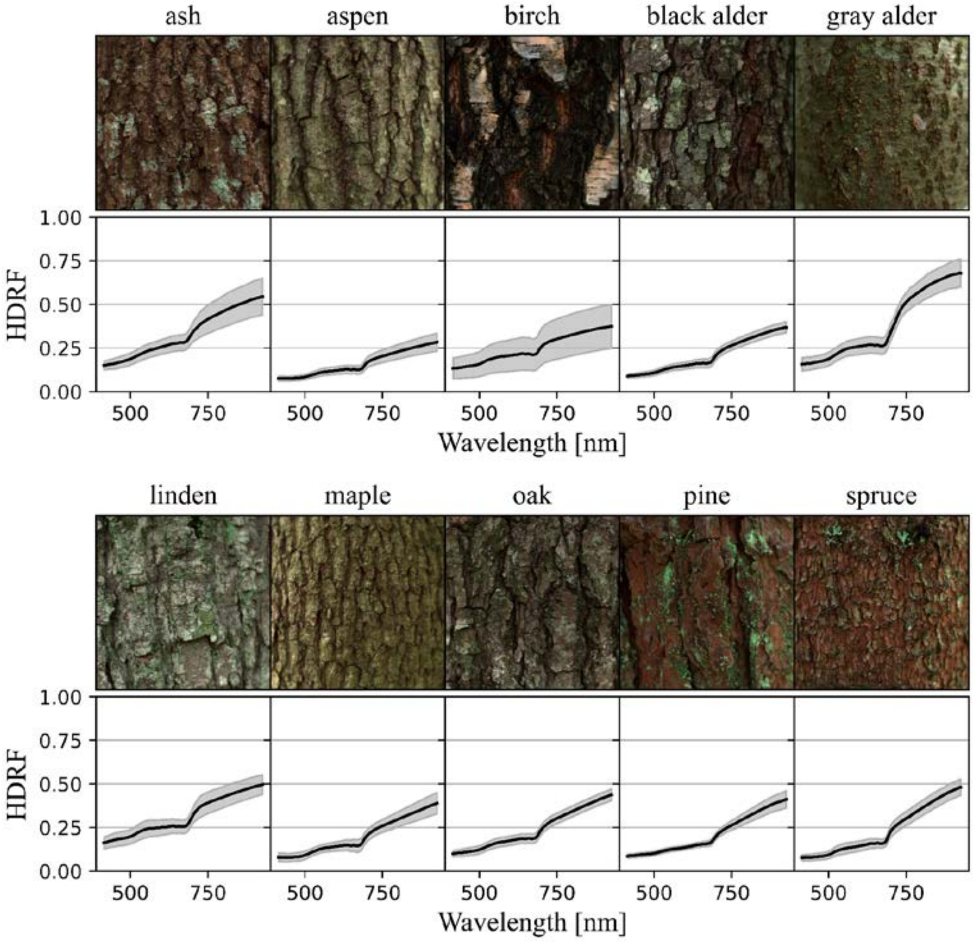
With the recent development of portable hyperspectral imaging spectrometers, there is a unique opportunity to acquire detailed information on the spectral properties of individual forest canopy elements, such as tree stems. Information on the spectral properties of stem bark is important for remote sensing of forests, biodiversity mapping, and forestry applications. In remote sensing, information on the fine scale physical interactions between shortwave solar radiation and stem bark is needed to interpret remotely sensed signals of forests more accurately. For biodiversity mapping and forestry applications, information on the spectral properties of stem bark could be used to support accurate identification of tree species. The aim of this dissertation was to develop close-range imaging spectroscopy as a method to measure the reflectance of stem bark in laboratory and field conditions, explore the spectral characteristics of stem bark, and assess the use of spectral data on bark in the identification of boreal and temperate tree species.

The results demonstrated that there is potential in utilizing close-range imaging spectroscopy as a novel data source for studying the spectral characteristics of stem bark in the laboratory and in the field. The reflectance spectra of the measured boreal and temperate tree species had a similar shape in the visible to near-infrared region, but the overall levels of reflectance varied substantially within-and between-species. In general, stem bark reflectance for the measured boreal and temperate tree species was highly variable and anisotropic. Stem bark reflectance was affected by the spatial location of the sample along the stem and by the angular effects associated with the view-illumination geometry. Greatest interspecific differences in stem bark reflectance were in the near-infrared region and varying absorption features were observed at around 670–700 nm. The spectral features of stem bark were robust for identifying tree species but combining them with the texture features extracted from the hyperspectral reflectance images improved results further. The results also underlined the importance of accounting for meteorological and radiation conditions when measuring the spectra of stem bark in field conditions with pushbroom sensor technology.

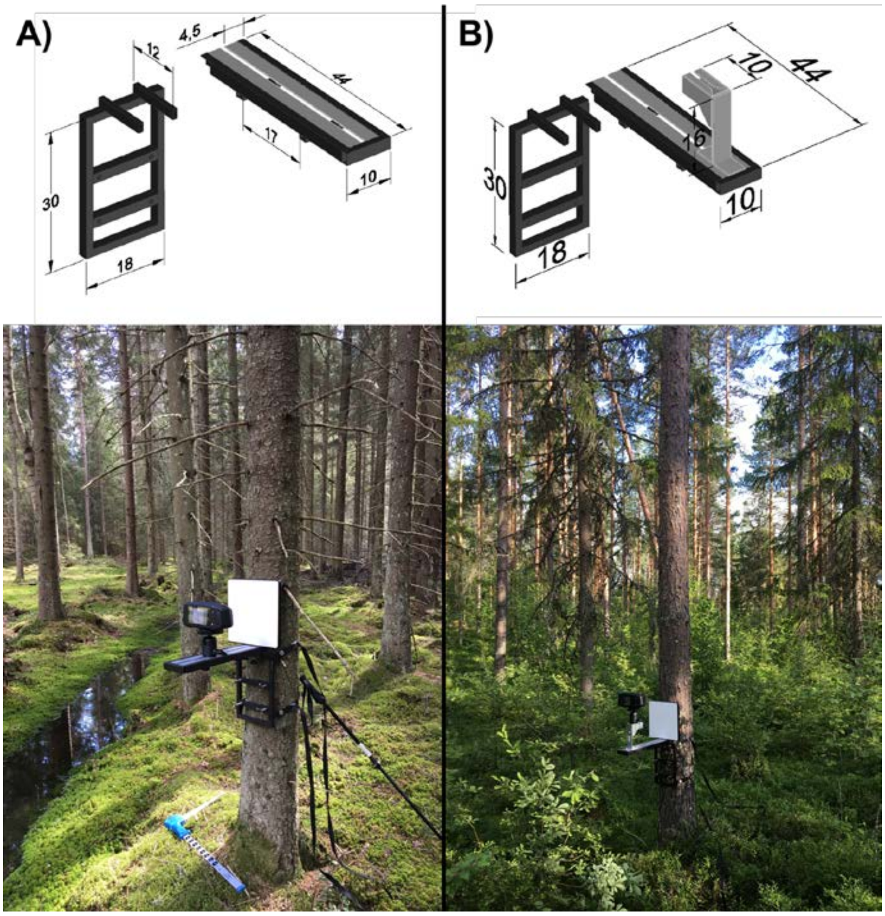
This dissertation gave a unique perspective into the spectral characteristics of stem bark for boreal and temperate tree species. The results contributed towards understanding the spectral diversity of forests more comprehensively and the portable hyperspectral imaging spectrometer showed promising results as a new technology for developing tree species identification methods for the forest industry and biodiversity mapping applications.

Keywords: forest, tree, stem bark, close-range, remote sensing, reflectance, hyperspectral, imaging spectroscopy

Highlighted figures from the thesis



Visual examples of hyperspectral reflectance (hemispherical-directional reflectance factor, HDRF) data cubes of tree stem bark samples measured for ten boreal and temperate tree species in the field. Visual example of each tree species is accompanied with the intraspecific mean (black solid line) and ±1 standard deviation (gray shaded region) of HDRF quantities. Adapted from Study III (https://doi.org/10.1080/22797254.2022.2161420) (CC BY-SA 4.0, https://creativecommons.org/licenses/by-sa/4.0/)



Illustrations and respective photographs of the field measurement set-up used in two configurations: A) sequential data collection in Study II (left), and B) simultaneous data collection in Study IV (right). Illustrations and photographs are from Studies II (https://doi.org/10.1002/ece3.8718) and IV (https://doi.org/10.1016/j.rse.2023.113837) (CC BY-SA 4.0, https://creativecommons.org/licenses/by-sa/4.0/).

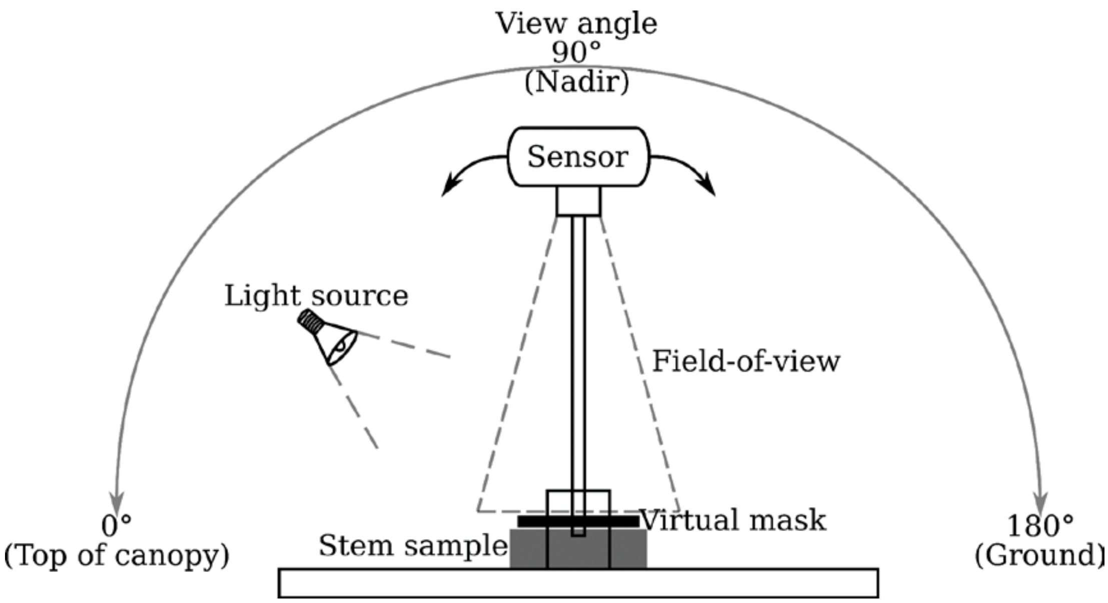
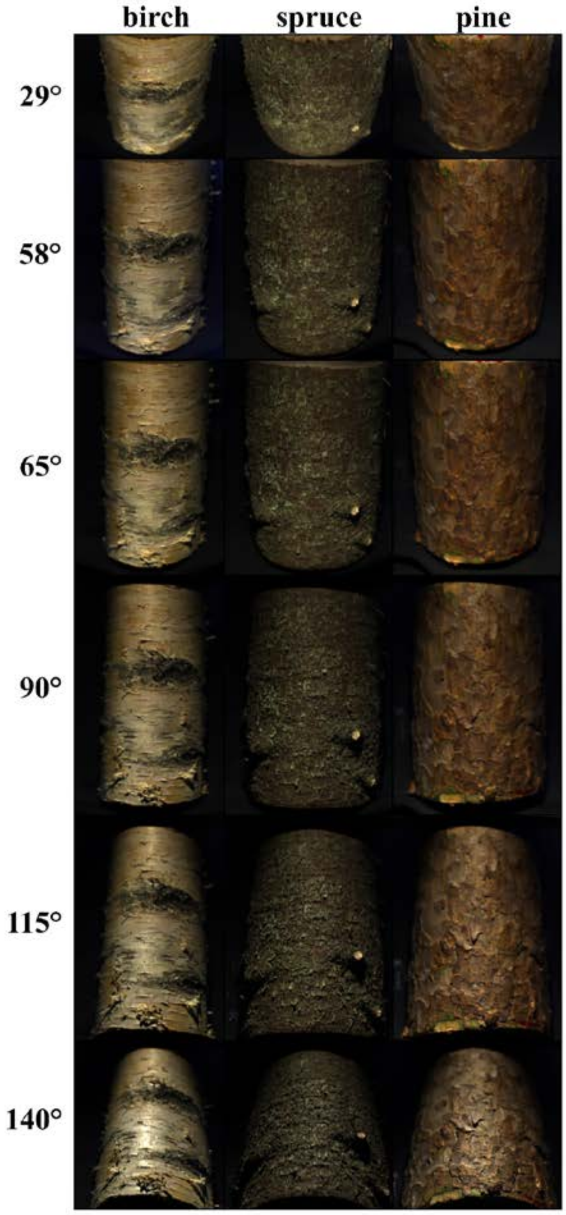


Illustration of the laboratory set-up for multiangular spectral measurements of stem bark samples. The illustration is from Study I (https://doi.org/10.14214/sf.10331) (CC BY-SA 4.0, https://creativecommons.org/licenses/by-sa/4.0/).



Visual examples of silver birch (left column), Norway spruce (middle column), and Scots pine (right column) stem bark samples measured from six different view angles (row-wise 29°, 58°, 65°, 90°, 115°, and 140°) with a multiangular laboratory set-up. The images are Red-Green-Blue, i.e., RGB, (wavelengths selected: 598 nm, 548 nm, 449 nm, respectively) image composites from the original hyperspectral reflectance images measured in Study I (https://doi.org/10.14214/sf.10331). Note the visual changes in bark reflectance depending on the view angle.