PhD Project Advertisement

Project title: How to improve measurement of major wheat diseases using artificial intelligence?
Project No: FBS2023-39-Mikaberidze-rc

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Project description:

Fungal diseases significantly reduce the global wheat harvest and threaten food security worldwide. Especially damaging are the five diseases that affect wheat leaves: septoria tritici blotch (STB), yellow rust (YR), brown rust (BR), powdery mildew (PM), and tan spot (TS). The goal of this project is to devise a new way to measure the five diseases by analysing digital images of wheat leaves using artificial intelligence (AI).

The student will develop the new method that will be more accurate than existing methods and enable faster measurements. This will greatly improve the quality and expand the scale of monitoring of wheat diseases. Knowledge acquired in this way will help farmers to adopt more sustainable practices to manage wheat diseases following integrated pest management (IPM). Current large-scale monitoring [e.g., by the UK Department of Environment, Food and Rural Affairs (DEFRA)] uses visual scoring, which limits the number of fields that can be sampled at a given budget and restricts measurement accuracy/reproducibility. This limits the resulting datasets in their quality and scale, and impedes adoption of IPM. Current ways to analyse digital images of wheat leaves cannot overcome this limitation: they do not distinguish between major wheat diseases and cannot be used with leaves collected in the field that exhibit a great diversity in their visual appearance.

Project goal

The student will overcome these limitations by devising a new AI-enabled way of detecting the presence and quantifying the amount of five major fungal diseases of wheat in the field, based on digital image analysis.

Objectives

First, the student will develop a new method to detect the presence of each disease and distinguish between the five diseases using digital images of wheat leaves (Objective A). To achieve this, the student will use AI techniques for image classification. This will allow the student to measure the proportion of symptomatic leaves for each disease (disease incidence).

Second, the student will develop a new method to quantify the amount of each disease within leaf images (Objective B). To achieve this, the student will use AI techniques for image segmentation. This will allow the student to measure the proportion of the leaf area covered by symptoms of each disease (disease severity). To achieve Objectives A and B, we will need reference datasets containing leaf images for which we already know their disease status (to enable image classification), and which pixels within the image correspond to healthy or diseased leaf areas (to enable image segmentation). The resulting AI models will perform only as good as permitted by the quality of reference datasets. Therefore, bringing together high-quality reference datasets is a key aspect of the project.

For STB and YR, extensive datasets containing thousands of leaf images were already collected in the lead supervisor's lab. They come from diverse sets of wheat varieties and capture the entire range of disease levels. To acquire reference datasets for the three remaining diseases (BR, PM and TS), the student will conduct a replicated field experiment with fifteen wheat cultivars representing different levels of resistance to each disease and contrasting visual characteristics of leaves. The student will capture sufficient numbers of digital leaf images (>500 for each of the three diseases) resulting from natural infections via destructive sampling using an established technique. This will allow the student to train the CNN models to detect disease presence and quantify the amount of each of the five diseases.

To further increase the speed of measurements and improve the logistics of disease monitoring, we will develop the PhenoBox, a portable platform that allows capturing high-quality images of wheat leaves in the field and in a rapid, nondestructive manner (Objective C). It consists of a robust plastic box that blocks ambient light, with a photocamera and a light source mounted at the top, and a slit at the bottom to insert the leaves. The student will test the PhenoBox's prototypes in the same field experiment, and once a working configuration is achieved, we will produce several copies of the best prototype and the student will test them using a subset of actual Defra's surveys (Objective D). This will allow the student to evaluate the gain in accuracy and speed of the new method compared to existing methods.

Training opportunities:
The student will acquire advanced skills in measuring and modelling plant diseases and using state-of-the-art artificial intelligence methods to detect and quantify diseases on digital images; hands-on skills in designing and conducting field experiments with wheat; experience in collecting, managing and analysing complex datasets. Supervisors will provide appropriate training and guidance on conceptual and methodological aspects of the project, including in-depth training in plant pathology and population biology of plant pathogens; advanced data analysis; plant disease epidemiology and modelling; computer programming and AI.

The student will attend a summer school on artificial intelligence/image analysis, a national conference and an international conference. Collaboration with ADAS and DEFRA and participation in wheat disease surveys of farmers' fields will help the student to acquire valuable transferable skills, provide them with an important perspective of the industry and policy-makers, and help them build their professional network. The student will be embedded within the extensive international collaborative network of the supervisors that includes plant pathologists, modellers, data scientists and computer scientists. The powerful combination of empirical, mathematical and computational skills, and a valuable professional network developed during the project will increase the student’s employability across academia, government agencies and industry.

Student profile:
The project suits a student interested in combining artificial intelligence and mathematical approaches to model agri-food biosystems with field experimentation. Candidates should have a BSc (minimum qualification is upper second class honours or equivalent) in a quantitative discipline such as computer science, physics, or mathematics; or in biological, environmental or agricultural sciences. Candidates should also have an interest in biology and computer science applied to agriculture. Experience in programming, artificial intelligence or computational biology are useful, but not essential, as appropriate training will be provided. We encourage applicants from diverse backgrounds.

Stipend (Salary):
FoodBioSystems DTP students receive an annual tax free stipend (salary) that is paid in installments throughout the year. For 2022/23 this will be £17,668 and this will increase slightly each year at rate set by UKRI.

Equality Diversity and Inclusion:
The FoodBioSystems DTP is committed to equality, diversity and inclusion (EDI), to building a doctoral researcher(DR) and staff body that reflects the diversity of society, and to encourage applications from under-represented and disadvantaged groups. Our actions to promote diversity and inclusion are detailed on the FoodBioSystems DTP website.

In accordance with UKRI guidelines, our studentships are offered on a part time basis in addition to full time registration. The minimum registration is 50% FT and the studentship end date will be extended to reflect the part-time registration.

References:

Karisto, P., Hund, A., Yu, K., Anderegg, J., Walter, A., Mascher, F., McDonald, B.A., & Mikaberidze, A., 2018 Ranking quantitative resistance to Septoria tritici blotch in elite wheat cultivars using automated image analysis, *Phytopathology*, 108, 568–581. https://doi.org/10.1094/phyto-04-17-0163-R

Anderegg, J., Hund, A., Karisto, P., Mikaberidze, A., 2019 In-field detection and quantification of septoria tritici blotch in diverse wheat germplasm using spectral-temporal features. *Frontiers in Plant Science*, 10, 1355. https://doi.org/10.3389/fpls.2019.01355

For up to date information on funding eligibility, studentship rates and part time registration, please visit the FoodBioSystems website.