PhD School on Agriculture, Environment and Bioenergy

(http://sites.unimi.it/dottorato_aab/)

(XXXVII cycle, 2021-24)

Project draft

1.Field of interest

AGR/09 Farm Machinery

2.Project title

3D sensing and automation technologies in high-precision agriculture

3.Tutor

Roberto Oberti

4. Relevance of the topic and state of the art:

Three dimensional (3D) measuring instrumentation, such as stereoscopic cameras or light detection and ranging (LiDAR) sensors, has being used since decades for automation and robotic research in laboratory conditions aimed at sensing, localizing or recognizing specific objects in an unknown environment. In the last 10-15 years these techniques have found interesting applications in plant phenotyping, with specific goals aimed at the extraction of 3D geometric features for shoot and canopy architecture analysis (Forlani and Schurr, 2013).

Anyway, due to the technological complexity and costs, these developments were mostly limited to advanced phenotyping customized platforms or to research prototypes. The recent introduction of low-cost 3D imaging sensors as Microsoft Kinect, Intel Realsense etc., made available affordable, yet sophisticated, systems disclosing new and diffused applications of 3D measurement systems. This is reflected by the ongoing booming of 3D imaging developments in plant phenotyping with applications at very different scale and complexity (Paulus, 2019).

On the other hand, the availability of reliable and cost-effective sensors discloses huge potential also for new applications of 3D in crop management technology and farm equipment which can still be considered at initial blossoming. Having access to precise 3D geometry data of the plant/organs in field conditions enables a potential of high-precision control of parameters in agricultural operations, a non-exhaustive list of which includes: the accurate yield sensing/prediction of fruit crops; the autonomous guidance of agricultural platforms or automatic positioning of working tools; canopy optimised spraying; crop/weed discrimination for ultra-precision weeding (Edan et al., 2021).

5.Layout of the project (draft)

5.1.Materials & Methods:

The PhD project will study and develop two demonstration cases relevant for precision agriculture technology. The activities will implement the full integration of 3D imaging sensor and associated algorithms with the automated control of carrier platforms required for plants revisiting capability and/or for optimizing the 3D measurement of the structures of plants.

The first case of study will be focused on 3D based measurement of the homogeneity of emergence, early vigor and growth rate of crop plants. The processed data will aim to provide real-time information on crop establishment and growth, resulting in background knowledge for optimizing the management at very-high spatial resolution or even to target additional transplanting where crop establishment fails.

A second case of study will apply 3D imaging techniques to discriminate crop and weeds plants based on their size and shape/morphology. These geometrical features can be extracted and quantified by 3D processing, fostering the classification capability (weed/crop, weed macro-categories, etc) obtained in classical top view imaging, which to date appears the most promising technological approach to weed sensing, but that is prone to significant limitations when seedlings develop in size and cause occlusions and overlapping of leaves/plants.

Weed/crop discrimination setup and algorithms will be integrated in an automated sprayer for a final demonstration of selective, high-precision weeding operations in experimental micro-plots.

5.2.Schedule and major steps (3 years):

Year 1. Literature review and identification of the most suitable 3D approaches for crop establishment, growth measurements and shape/geometry indicators of plant species. Setup, optimization and test of a 3D imaging system in lab and greenhouse conditions. Algorithms prototyping.

Year 2. Database of greenhouse measurements on emergence and growth-rate of crop plants (corn, vegetables). Database of greenhouse measurements on mixtures of weeds (selected species) and crops (corn, vegetables). Development of pipeline analysis for emergence and growth monitoring, and for weed/crop discrimination based on size and shape.

Year 3. Outdoor experiments on micro-plots with automated 3D measurements from an autonomous platform/rover. Time-repeated measurements of crop emergence and growth monitoring with the production of high-precision maps for crop emergence homogeneity/failure and for biomass growth rate. Experiments on autonomous early detection of weeds and demonstration of automated, intra-row precision weeding.

6. Available funds (source and amount)

90 k€ (ASIMP-ISR/ITA2019-22; MIND FOODHUB 2020-23; Liberal funds)

7. Literature

Paulus S. 2019. Measuring crops in 3D: using geometry for plant phenotyping. Plant Methods 15, 103

Forlani F and Schurr U. 2013. Future Scenarios for Plant Phenotyping. Annu. Rev. Plant Biol.. 64:267-291

Edan Y, Adamides G., Oberti R. 2021. Agriculture Automation. In: Springer Handbook of Automation (2nd ed.), edited by Nof SY. Spriger

Piron A, van der Heijden F, Destain MF (2011) Weed detection in 3D images. Precis Agric 12:607–622

Andújar D, Dorado J, Fernández-Quintanilla C, Ribeiro A (2016) An approach to the use of depth cameras for weed volume estimation. Sensors 16, 972.

Bulgari R, Morgutti S, Cocetta G, Negrini N, Farris S, Calcante A, Spinardi A, Ferrari E, Mignani I, Oberti R, Ferrante A. 2017. Evaluation of borage extracts as potential biostimulant using a phenomic, agronomic, physiological and biochemical approach. Frontiers in Plant Science: 8: 9351-9356.