4.20 Aerial-Based Precision Agriculture

Unmanned aerial vehicles (UAVs for short) have recently begun being applied to precision agriculture. This is a new development and results are still preliminary, albeit very promising. In fact, the Association for Unmanned Vehicle Systems International forecasts that 80% of all UAVs sold in the United States in the 2015-2025 period will go to serve the agricultural market [88]. Even if the actual figure turns out not to be that high, there is no question that roboticists and agricultural engineers are investing significant time and resources to understanding how UAVs can improve agricultural efficiency and reduce costs.

Dong et al. [89] use high-resolution images and on-board sensor data from an aerial vehicle (Figure 36) to create a sequence of dense 3D reconstructions of the crop over time. This 4D spatio-temporal reconstruction is used to segment the canopies and estimate how the crown radius and height of each plant evolve. The processing pipeline was tested on data collected in a field planted with corn, broccoli, and cabbage in Tifton, GA, USA (Figure 37).

Figure 36. AscTec Pelican quadrotor used for data collection over early season sweet corn.

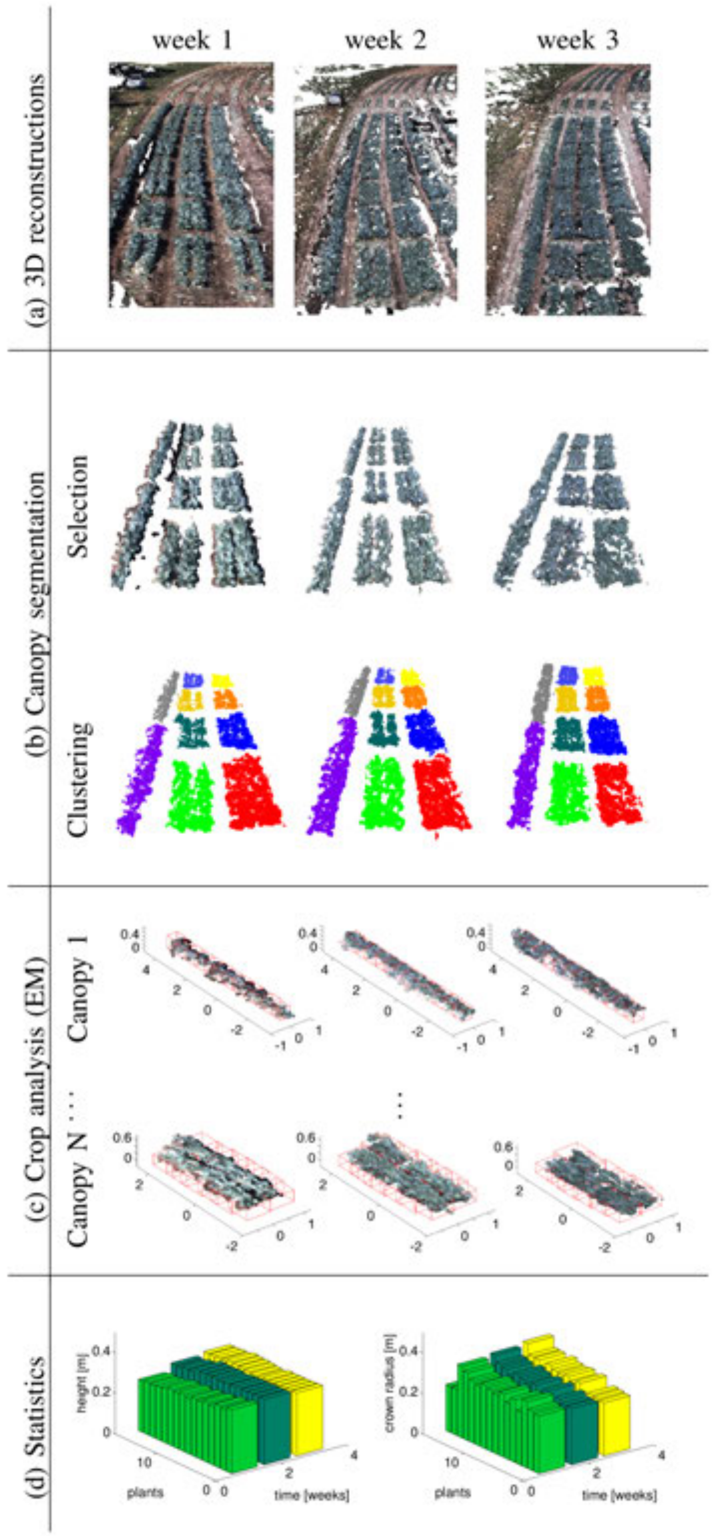

Figure 37. Dense 3D reconstruction of the corn stalks, used to estimate how the crown radius and the height of each plant evolve over time.

In many potato growing areas, the potato crop does not senesce naturally and therefore tuber maturation is artificially induced by killing the haulm 10 to 25 days prior to harvest. Reglone is a widely used potato haulm killing herbicide. Building on the knowledge of the relationship between potato crop biomass status, expressed in Weighted Difference Vegetation Index (WDVI) [90], and the minimum effective dose of Reglone, Kempenaar et al. [91] successfully demonstrated the use of crop biomass imaging with a multi-spectral camera underneath an unmanned aircraft (Figure 38) for variable rate application. The WDVI map was converted into a 33 x 10 m dose grid map (Figure 39) adjusted to the boom width of the field sprayer. On the field, the average use was 0.9 liters of Reglone per ha, with satisfactory efficacy. Standard practice would have been the use of 2 liters per ha. The use of unmanned aerial imaging thus prompted a savings of more than 50%, without loss in potato haulm killing efficacy, harvestability of the potatoes, and final product quality.

Figure 38. Operator launching an unmanned aircraft over a potato field via a launch rope. The plane then flies autonomously following a pre-programmed flight path.

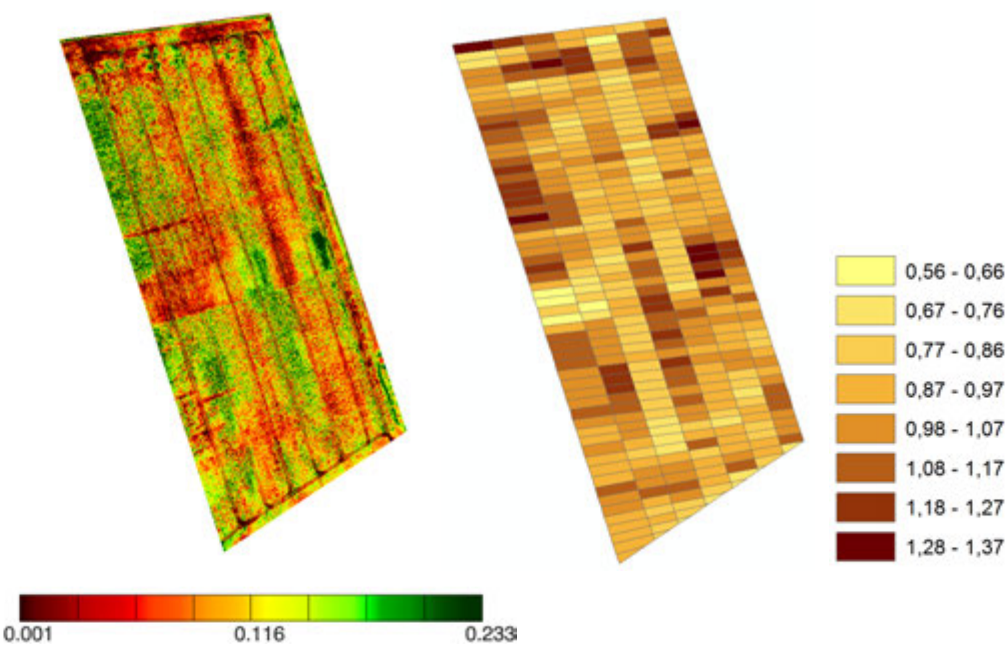

Figure 39. (Left) Weighted Difference Vegetation Index map of a potato field; the legend on the bottom represents the WDVI, which varies from zero (no crop at all) to one (theoretical maximum). A vigorous potato crop has a value in the 0.6-0.7 range. (Right) Reglone dose task map; the legend represents dose in liters per hectare.

Wheat is the most widely grown arable crop in the UK, covering around 1.6 million hectares and producing 11.9 million metric tons in 2013. As with other crops, wheat has its share of weed competitors, one of which is black-grass. This prolific weed is highly competitive and increasingly resistant to chemical control, making it one of the biggest challenges facing UK's arable sector.

Researchers from URSULA Agriculture have demonstrated a system that combines multispectral sensing with UAVs to capture imagery at 10 cm resolution (Figure 40) [92]. Using the unique spectral and morphological properties of the black-grass, they developed classification processes that are applied to the image to automatically delineate the black-grass from the host crop.

For the farmer and agronomist, the output is supplied in the form of visual maps and spatially attributed data points that are transferable through farm planning software to precision guided machinery (Figure 41). URSULA Agriculture's imagery analysis is able to not only identify the location and in-field extent of black-grass infestation, but also the density and area of black-grass plants, all of which will have a bearing on control decisions. The information provides the farmer with vital data to help contain black-grass infestation in the current growing season. Crucially, it also helps with long term control by informing management methods such as higher seed rates to increase competition in black-grass 'hotspots,' alternative cultivation techniques, or adjusting cropping strategies, all of which can help control black-grass alongside chemical herbicides.

Figure 40. Fixed-wing UAV launched over a black-grass infested wheat field.

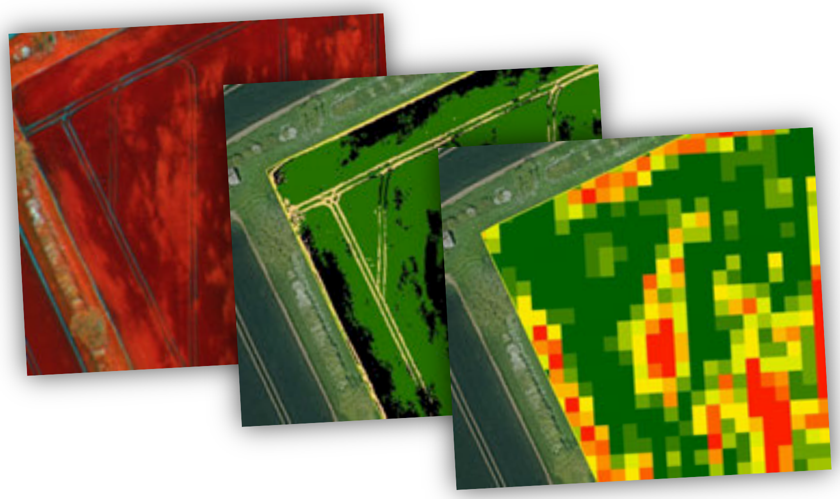

Figure 41. Black-grass analysis stack: High-resolution multispectral image (left), black-grass delineation (center), and density map (right).

[84] Y. Wang, W. Yang, P. Winter, L. T. Walker, 2006. Non-contact sensing of hog weights by machine vision, Applied Engineering in Agriculture, 22(4):577.

[85] S. Westerberg, I. Manchester, U. Mettin, P. La Hera, A. Shiriaev, 2008. "Virtual Environment Teleoperation of a Hydraulic Forestry Crane", IEEE International Conference on Robotics and Automation.

[86] Wikipedia. "Controlled Traffic Farming." Available at http://goo.gl/FODY04.

[87] W. Zhu, F. Zhong, X. Li, 2010. Automated Monitoring System of Pig Behavior Based on RFID and ARM-LINUX, Third International Symposium on Intelligent Information Technology and Security Informatics, pp.431-434.

[88] Association for Unmanned Vehicle Systems International, 2013. "The Economic Impact of Unmanned Aircraft Systems Integration in the United States." Available at http://goo.gl/H5AEzF.

[89] J. Dong, L. Carlone, G.C. Rains, T. Coolong, and F. Dellaert, 2014. "4D Mapping of Fields using Autonomous Ground and Aerial Vehicles." ASABE International Conference, Montreal, Quebec, Canada, Paper No. 141912258. (doi: 10.13031/aim.20141912258).

[90] F.K. van Evert, P. van der Voet, E. van Valkengoed, L. Kooistra, C. Kempenaar, 2012. "Satellite-based herbicide rate recommendation for potato haulm killing." European Journal of Agronomy 43: 49–57.

[91] C. Kempenaar, F.K. van Evert, Th. Been, 2014. "Use of vegetation indices in variable rate application of potato haulm killing herbicides." Proceedings of ICPA Conference, Sacramento, USA, July 2014.

[92] C. Pugh, M. Jarman, S. Keyworth, J. Webber, and I. Cameron, 2013. URSULA Agriculture. Available at http://goo.gl/HzGkRT.