AUTOMATIC DETECTION OF BROAD-LEAVED DOCK IN GRASSLAND

T. Anken[1], D. Šeatović[2], M. Holpp[1], W. van de Venn[2], H.J. Kutterer[3]
[1] Agroscope Reckenholz-Taenikon Research Station ART, Taenikon, Ettenhausen – Switzerland, e-mail: thomas.anken@art.admin.ch
[2] Institute of Mechatronic Systems IMS, Winterthur, Switzerland
[3] Geodetic Institute of Leibnitz, University of Hannover, Germany

Abstract
Broad-leaved dock (rumex obtusifolius) is one of the most competitive and persistent weeds in grassland. Plant by plant treatments are very time consuming and chemical treatments of the whole surfaces are unecological, not selective and cause yield depressions.
A prototype of an automatic recognition and single plant-treatment system has been developed and tested under field conditions. The sensing unit consists of an infrared-laser triangulation sensor combined with a high-resolution smart camera to generate three-dimensional images of the grassland. In a segmentation process, three dimensional surface patches are recognised, straightended and compared with different criteria of a plant database containing surface parameters such as shape and state of surface. If an object is recognized as a dock leaf, the leaves are sprayed with herbicide. The surface analysis in space boosts the recognition performance under conditions where state-of-the-art two-dimensional systems are not successful like pictures with low contrast due to overlapping leaves. Initial results are promising. System development focuses on a more robust imaging sensor technique and refinement of the different algorithms. Looking to the future, the system design allows the flexible integration of other plant species.

Keywords: Image analysis, plant recognition, rumex obtusifolius, robotics

Introduction
Image processing and localization may help in replacing the human capacity for observation and decision making by technology. Apart of the automation of manual tasks this technology is the key for single plant treatment like this is the case for broad-leaved dock (*rumex obtusifolius, Fig. 1*). Segmentation is the crucial part of data analysis and ranges from simple binarization of images to complex analysis of multispectral images and multidimensional data. An initial step of the segmentation is edge extraction. A variety of algorithms have been published and evaluated in machine-vision literature. A 2D broad-leaved dock recognition system requiring powerful computing resources for the segmentation of high-resolution images is described in various papers (Gebhard et al. 2006, Gebhard 2007, Gebhard and Kühbauch 2007). The main benefit of using the third dimension is that, with the help of height information, it actually enables the segmentation of plant leaves in very cluttered and complex environments such as can be found in meadows. With this technical background an automated recognition, localization and treatment system for broad-leaved dock was developed. The high-resolution 3D ground-data segmentation approach enables real-time plant recognition and the application of herbicides to the plant leaves.

Fig. 1. Broad-leaved dock (*Rumex obtusifolius*)

Material and Methods

SmartWeeder – automated detection and spraying of dock plants

A prototype to detect and to spray identified broad-leaved dock plants has been built. This prototype is described in (Šeatović and Grüninger 2007, Šeatović 2008, Šeatović et al. 2008b). This prototype consists of a detection, a computation and a spray unit.
A row sensor consisting of a laser beam and a high resolution smart camera (laser triangulation system) are used to scan three dimensional (3D) images line by line (Sick Ranger C55, Waldkirch, D). As the sun sensitivity of the camera is the main noise source, the vehicle is equipped with a black cover (Fig. 2). Every new measurement produces a new vector of 3D points. The system has different scales in x, y and z coordinate axis. The processing of the data succeeds following sequential steps. First step: Pre-processing includes filtering, edge detection and 3D connected components labelling. Second step: Recognition includes joining the surface patches, projection of the surface boundary to the plane, analysis of the boundary with help of the elliptic Fourier descriptors and classification with help of support vector machine.

Fig. 2: Left: SmartWeeder processes 3D-images by means of a laser triangulation system. Right: SmartWeeder in action. The detected plants are sprayed by single nozzles. Source: Agroscope ART

Data processing

Raw data is filtered so that very small surface patches are removed. With this reduction of the input data, dust, insects and small noise speckles are erased. In the next step, for every single point with its neighbourhood situation will be analyzed and then in the last step of pre-processing the edge detection algorithms will be applied (Fig. 3). After the edge detection was completed, the connected components procedure can start. In this step every measured point will be assigned to the corresponding surface patch. Result of this procedure is shown in the Figure 4. On the right, white and grey dots are representing edges. Coloured surfaces represent surface patches. At this stage one leaf can contain more than one label, if so, then multiple colours are shown for that surface.

The main processing step analyzes the neighbourhood relations between the surface patches created by the connected components algorithm. In cluttered areas boundary boxes overlap for every occurring surface patch. All patches have to be copied into the recognition buffer. Due this constrain, overlapping areas are repeatedly copied, for every patch. Result of the copy procedure is shown in the Figure 5, on the left hand side. Small grass patches and clover leaves are removed and the recognition task has clearer situation for the following shape analysis.

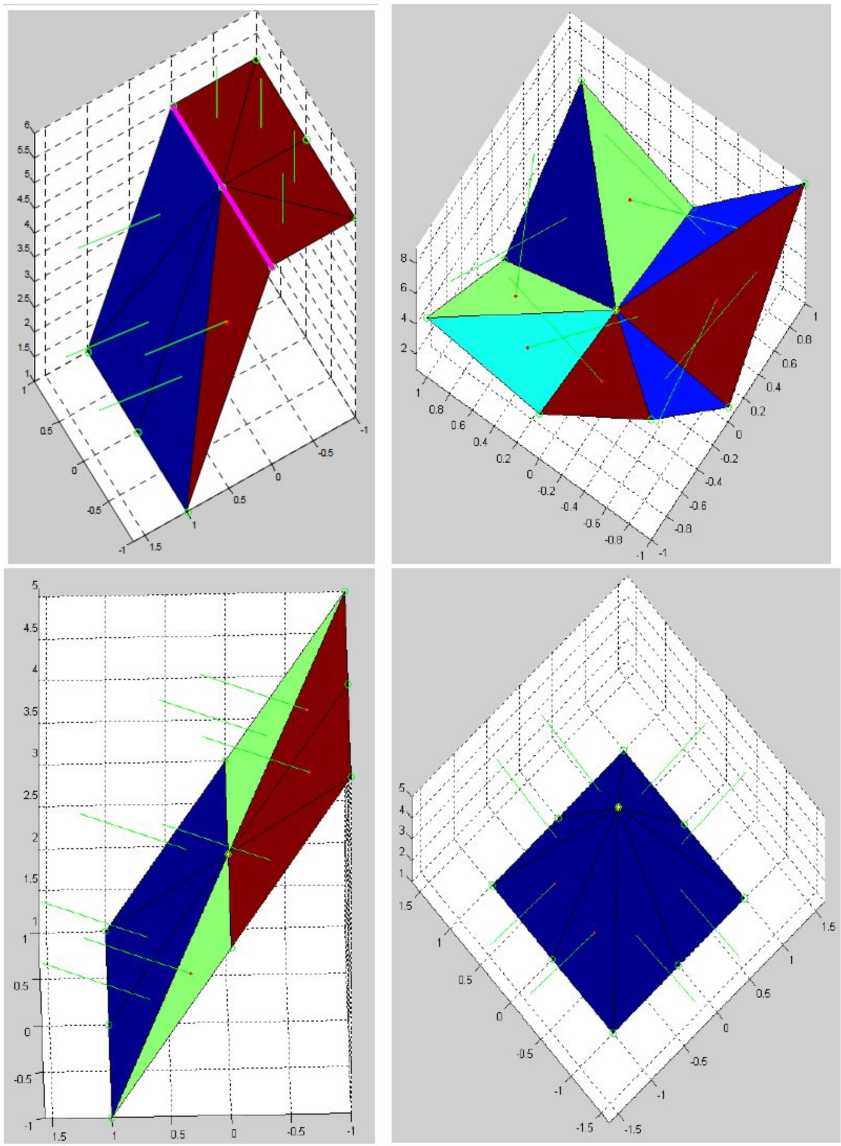

Fig. 3: Top left: Edge detection in the 9-point neighborhood. The center point is an edge point. Upper right: No edge: the center point is in the diffuse vector field. Bottom left: No edge: all vectors point in same direction. Bottom right: The center point is a node, and there are multiple edges gathering in the center of the patch.

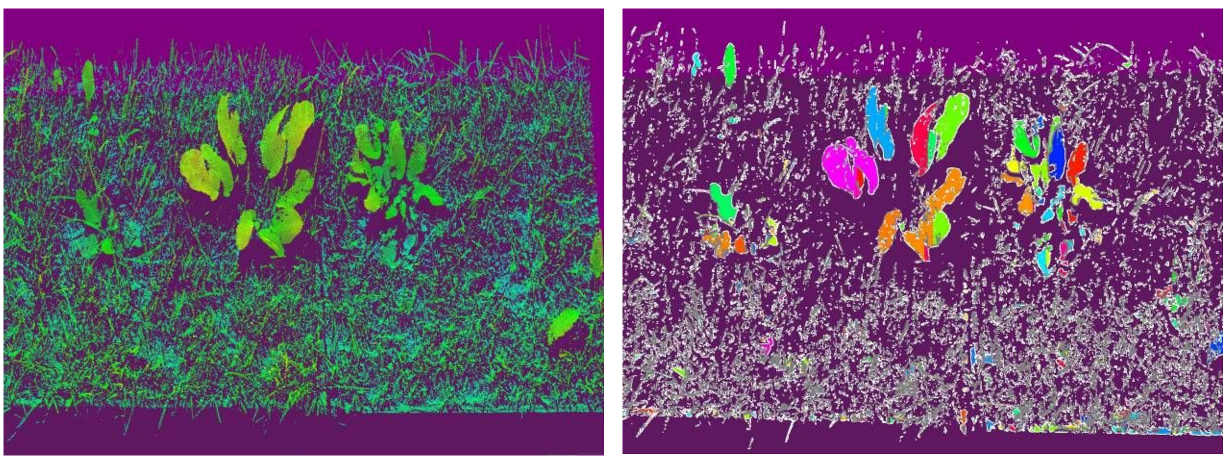

Fig. 4 Left: Raw 3D data acquired by the sensor, warmer colours represent higher points. Right: Same 3D data processed by the pre-processing steps.

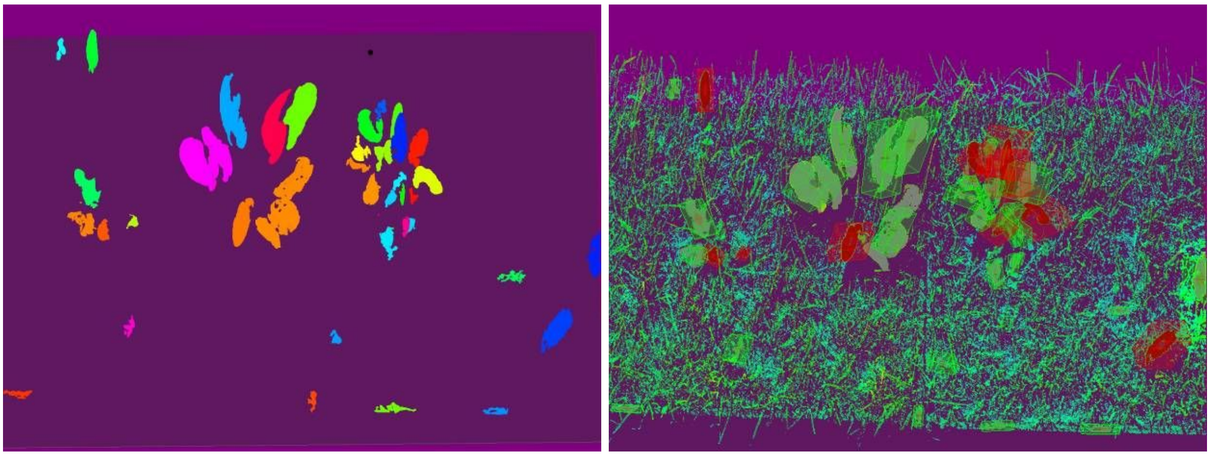

Fig. 5 Left: Objects passed to the recognition buffer. Different colours represent different labels of the objects. Right: Result of the classification, red boxes are confirmed Rumex leaves, green-grey boxes surround rejected surfaces (not-Rumex).

In recognition step, all candidates are projected from the 3D-surfaces to the plane 2D-footprints of the leaves. The transformation currently projects the boundary points to the plane defined by the proper vectors computed out of the 3D point cloud. Every object in the recognition buffer contains also its distribution with corresponding distribution moments. With help of eigenvector computation, orientation, middle point, etc. are computed and stored for every object. Two largest eigenvalues with corresponding eigenvectors define projection plane for the shape analysis. Boundary points of the projected shape are used to compute elliptic Fourier descriptors. These are used as features for the classification of the shape (Neto et al. 2006). Classification succeeds with help of the support vector machine classifier. For this purpose we use already implemented library (libSVM) of Chih-Chung and Chih-Jen (2001).

Results

The prototype is actually working under real time conditions in a natural environment. Under simple conditions (broad-leaved dock between grasses) the detection rate is very high. Under more complicate conditions (dock between clover or other broad-leaved plants) the recognition rate still has to be improved. As soon as a leaf has been detected it will be sprayed by nozzles which are opened by means of electromagnetic valves what is working fine. For the treatment, only one leaf per plant need to be recognized. Neighbouring objects, up to 40cm distance, are tested on their rejection probabilities. If they are low, then the system treats the set of surfaces that belongs to dock plant and treats them all.

Discussion

The results obtained with the "SmartWeeder" prototype have shown that, 3D-Data acquisition, robust segmentation and high data quality enable reliable and fast classification of the leaves. 3D-Data are by far more powerful than the 2D vision systems, especially considering robust segmentation and shape analysis. 3D data processing needs considerably more computing resources than its pendants in 2D. Though, new more powerful multi-core computing systems are state of the art on the market and with the help of parallel algorithms, performance will significantly be improved.

The next project step is the implementation of analysis algorithms for the extracted surfaces in the recognition task. Object classification makes the final decision as to whether or not the extracted surface is a dock leaf. For this purpose, shape analysis in 3D space will be combined with texture-analysis algorithms such as the one described in Gebhardt (2007).

Conclusions

The three dimensional detection of dock plants has shown a significant improvement of the recognition rate compared to two dimensional systems. Nevertheless, the presented work shows only the beginning of the exploitation of 3D-acquisition and treatment. Beside the detection of broad-leaved dock, this technique has the potential to detect other objects for different tasks in the field of plant protection, vegetable or fruit harvest and others.

Acknowledgments

The project has been made possible thanks to GEBERT RÜF STIFTUNG, which is providing start-up financing and monitoring progress. Many thanks to the people of the Foundation for the support far beyond only financial matters, for the patience and understanding.

References

Gebhardt, S. et al. (2006). Identification of broad-leaved dock (rumex obtusifolius l.) on grassland by means of digital image processing. In: Precision Farming. Number 3 in Precision Agriculture, Institute of Crop Science and Resource Management - Crop Science and Plant Breeding, University of Bonn, Katzenburgweg 5, D-53115 Bonn. Springer Netherlands, pp. 165-178.

Gebhardt, S. (2007). Automatic classification of grassland herbs in close-range sensed digital colour images. PhD thesis, Mathematisch-Naturwissenschaftliche Fakultät, University Bonn, 2007.

Gebhardt, S. and Kühbauch, W. (2007). A new algorithm for automatic rumex obtusifolius detection in digital images using colour and texture features and the influence of image resolution. In: Precision Farming. Number 1-2 in Precision Agriculture, Institute of Crop Science and Resource Management - Crop Science and Plant Breeding, University of Bonn, Katzenburgweg 5, D-53115 Bonn, Springer Netherlands, pp. 1-13, 2007.

Šeatović, D. and Grüninger, R. (2007). Smartweeder: Novel approach in 3d object recognition, localization and treatment of broad dock in its natural environment. In: RAAD 2007: Programme and Book of Abstracts.

Šeatović, D. (2008). A Segmentation Approach in Novel Real Time 3D Plant Recognition System. Proceedings of the 6th International Conference on Computer Vision Systems ICVS, Santorini, 2008.

Šeatović, D., Grüninger, R, Anken, T., Holpp M. (2008). 3D object recognition, localization and treatment of rumex obtusifolius in its natural environment.1st International Conference on Machine Control & Guidance, June 24-26, Zurich.

SICK. (2010) IVP Ranger, 3D vision system, Waldkirch, D. http://www.sickivp.com/sickivp/products/3d_cameras/ranger_highspeed/en.html

Neto, J. C. et al. (2006). Plant species identification using Elliptic Fourier leaf shape analysis. Elsevier, Computers and electronics in agriculture, no. 2, 121-134.

Chih-Chung C.and Chih-Jen L. (2001) LIBSVM: a library for support vector machines. 2001. http://www.csie.ntu.edu.tw/~cjlin/libsvm