Interactive Image Segmentation for Model Adaption and Decision Support

W. Strothmann, A. Kielhorn, V. Tsukor, D. Trautz, and A. Ruckelshausen
University of Applied Sciences Osnabrueck, Post box 1940, 49009 Osnabrueck, Germany

w.strothmann@hs-osnabrueck.de

Abstract

In many fields of Agricultural Management and Agricultural Engineering sophisticated algorithms based on complex environment models are used to generate decision-supporting information from various data sources. However, often these models highly depend on the proper adaption of their complex parameter sets to local ambient conditions and in many cases practitioners are not able to perform this adaption. Therefore a concept is shown here that allows the identification of objects in images and their linkage with meta-data in semi-automatic human-machine interaction. The approach combines the robustness of human experiences against spatially and temporarily local variations and the performance and reproducibility of statistical models. It can also be used as an easy way to adapt models to local ambient conditions, which allows recalibrating them more often, thereby increases stability against changes, iteratively improves them and opens the door for life-long machine learning.

The software has been developed within the collaborative research project RemoteFarming.1 in which a remote farming robotic weed control system is being developed. The robotic weed control system will be used for in-row weed treatment in carrots at BBCH-scales 10 to 20 in organic farming. In this field weed control is currently conducted by hand. Within the project's first part RemoteFarming.1a an autonomous field robot – based on the platform BoniRob - is being built. It is able to autonomously navigate on the field and has an actuator for mechanical treatment of weeds. Furthermore it uses synchronously triggered cameras and lighting units at different wavelengths which can capture high-contrast images of the plants in a shaded space underneath the robot. The detection/identification of weeds in RemoteFarming.1a is performed in a web-based approach by a remote worker, who marks the weeds in images captured by the robot on the field. Afterwards the mechanical actuator of the robot moves to those positions in the field which have been marked in the respective images and eliminates the weed plants. In the second part RemoteFarming.1b this system will be enriched with weed/crop classifiers and the detection/identification. The user will get a suggestion of possible weeds marked in his view and he can confirm or modify these suggestions before the weed will be treated.

The software framework described here allows iteratively generating segmentations for images by human-machine interaction. After a first-shot segmentation the user can add marks in the image and after any added mark the segmentation gets improved. The segmentation is visualized by a semi-transparent ImageMap overlaying the original image. The algorithms that have been tested for performing the segmentation so far are *Watershed* and *Graph-Cuts*. During the process any arbitrary segment in the ImageMap – even unconnected regions - can be assigned to an object. These objects then can be separated into groups and enriched with additional meta-data. Furthermore the ImageMaps can be grouped into Situations representing different field conditions.

The framework's design is flexible with abstraction of front-end and back-end. On the back-end side a server version saves data in a relational database. Alternatively a stand-alone version provides the same functionality using XML to persist data. For the front-end a web-based version can be deployed on servers. Another front-end is implemented as App. This allows using the framework on mobile devices even without Internet connection, saving the gathered data temporarily in XML and persisting into DB once connected.

The framework has been used within the collaborative research project RemoteFarming.1 for labeling of crop and weed plants. It allowed generating a sophisticated ground-truth for shape-matching algorithms and weed/crop classifiers. Regions of plants and even overlapping leafs have been marked, grouped to plants and assigned with labels (Species) and meta-data (BBCH-scale etc.). In the on-going project the system will be enriched with statistical models to provide the user improved first-shots for segmentation and plant classification. But geometric analyses of the labelled data collected at project beginning has already served as specific input for vague issues in requirement analysis for the remote farming robotic weed control system that will be developed.

Keywords: image segmentation, classification, weed control, remote farming.

TABLE OF CONTENTS

INTERACTIVE IMAGE SEGMENTATION for Model Adaptation and Decision support

Wolfram Strothmann[a], Arnd Kielhorn[b], Vadim Tsukor[a], Dieter Trautz[b], Arno Ruckelshausen[a]

[a]Faculty of Engineering and Computer Science – University of Applied Sciences Osnabrueck. Albrechtstrasse 30. 49074 Osnabrueck, Germany

[b]Faculty of Agricultural Sciences and Landscape Architecture – University of Applied Sciences Osnabrueck. Am Kruempel 31. 49090 Osnabrueck, Germany

Hochschule Osnabrück
University of Applied Sciences

Wolfram Strothmann
w.strothmann@hs-osnabrueck.de

9th European Conference on Precision Agriculture — Facing new challenges, providing new solutions — Lleida, Catalonia, Spain, July 7th-11th 2013

Introduction

The on-going research project RemoteFarming.1 is conducted in cooperation between UAS Osnabrück with the companies Robert Bosch GmbH and Amazonenwerke H. Dreyer GmbH. It aims to develop a remote farming robotic weed control system which integrates a human user as remote worker in the process. The robotic weed control system will be used for in-row weed treatment in carrots at BBCH-scales 10 to 20 in organic farming. Within the first part, RemoteFarming.1a is an autonomous field robot – based on the platform BoniRob (Ruckelshausen et al., 2009) - is being built which is able to autonomously navigate on the field and has an actuator for mechanical treatment of weeds. The detection/identification of weeds thereby is performed in a web-based approach by a remote worker, who marks the weeds in images taken by the robot in the field **(Fig. 1)**. In the second part, RemoteFarming.1b, this system will be enriched with weed classifiers and the detection/identification of weeds will be performed in shared autonomy, where – based on the results of automatic (image-) data processing - the user will get a suggestion of possible weeds marked in his view and he can confirm or modify these suggestions before the weed will be treated. The user inputs will be used to improve the weed classifier model and to adapt processing parameters to the current situation.

The central idea of the RemoteFarming.1 project is to integrate a human user as remote worker into the weed control process. Thus, it drastically reduces the complexity of a problem in heterogeneous environments by not aiming to solve it using a fully autonomous system but integrating user interaction as a crucial component in the process. This is especially valid for the software described here, which was developed as part of RemoteFarming.1. It has served for the labeling and data storage in RemoteFarming.1.

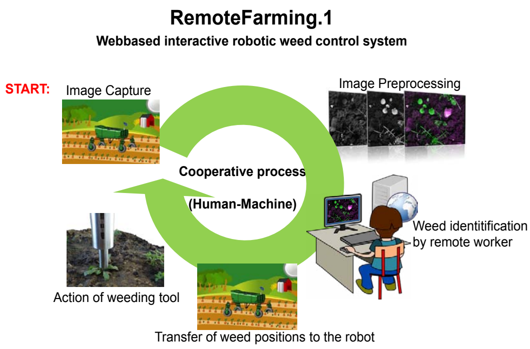

Figure 1. RemoteFarming.1 overview

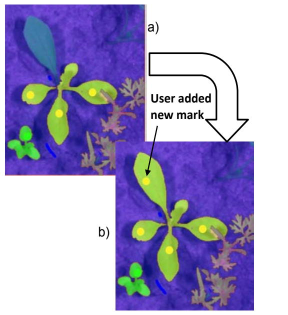

Figure 2. Segmentation update: Previous segmentation (missing a leaf) and updated segmentation, after a new mark was added by the user

Labeling and data storage

The developed software framework allows iteratively generating segmentations for images by human-machine interaction. After a first-shot segmentation, the user can add marks in the image and after any added mark the segmentation gets improved. During the process, the segmentation is visualized by a semi-transparent ImageMap overlaying the original image. An iteration of the segmentation process is shown in **Fig. 2**. **Fig. 2a** shows the previous segmentation which was updated to the segmentation in **Fig. 2b** as the user added one additional mark. The algorithms which have been tested for performing the segmentation so far are *Watershed* (Meyer, 1992) and *Graph-Cuts* for binary problems (Boykov & Jolly, 2001; Rother et al. 2004).

During the process any arbitrary segment in the ImageMap – even unconnected regions - can be assigned an object, which could – for instance - represent a part of a plant. These objects then can be separated into groups and be enriched with additional meta-data. Furthermore the ImageMaps can be grouped into situations representing different field conditions.

After this process, the ImageMap structure containing the original image, some kind of meta-data, an ImageMap matrix and a link to all objects marked in the image is saved. The object structures can also be enriched with labels and meta-data and saved along with the ImageMap information. In order to link the generated segmentation of the image with meta-data and groups of each object, the ImageMap overlay is filled with ID-based information. It is saved as an image with 8 bit depth per pixel wherein each pixel contains the information whether the pixel assignment was set by the algorithm or by the user and which object the pixel is assigned to. This is illustrated in **Fig. 3**.

The following example illustrates how the segmentation is visualized for the user and saved in the ImageMap matrix for labeled plants. The original image of overlapping plants is given in the left-hand side of **Fig. 4**. The plants in the image have been iteratively segmented by the user-machine interaction This generated the view shown in **Fig. 4** on right-hand side. In this view, the background and pixels assigned by the region-expanding algorithm are indicated as a semi-transparent overlay of the original image and the user's marks are opaque.

The framework includes abstraction layers for front-end and back-end, as illustrated in **Fig. 5**. The framework is written in *C++* making extensive use of the open-source computer vision library *OpenCV* (Bradski, 2000). On the back-end side, a server version saves data in a data-base using a *PostgreSQL* engine and an object-relational mapping. Additionally, a stand-alone version provides the same functionality using XML to store data. XML-files generated using the stand-alone version can also be synchronized into and from the data-base server. Apart from the web-based front-end, other user interfaces are possible, to provide flexibility for reuse in other projects.

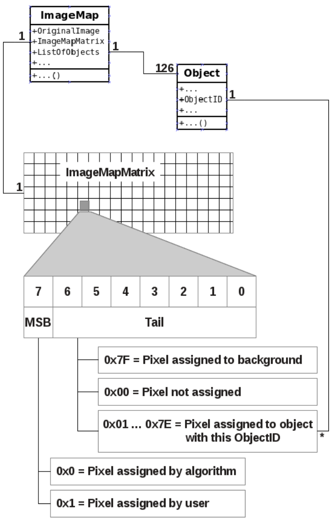

Figure 3. Linking segmentation and data-base entries

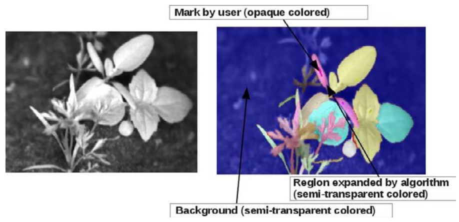

Figure 4. Visualizing segmentation as overlay (left: original image, right: user's view)

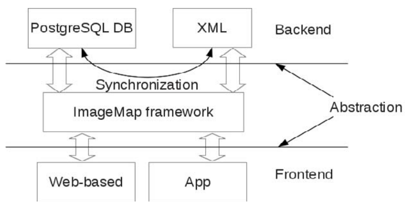

Figure 5. Design of the ImageMap

Outlook

The ImageMap frame work has been used in a web-based labeling tool for labeling of crop and weed plants as part of RemoteFarming.1. It allowed generating a sophisticated ground-truth for shape-matching algorithms and weed/crop classifiers. Regions of plants and even overlapping leaves have been marked, grouped to plants and assigned with labels (species) and meta-data (BBCH-scale etc.). It also allowed gathering experiences in marking and labeling of images through a web interface.

Geometric analyzes of the labeled data collected at project beginning already served as specific input for vague issues in requirement analysis for the remote farming robotic weed control system that is being developed. In the ongoing project, the system will be enriched with statistical model for the crop/weed plant detection and identification problem as part of RemoteFarming.1b.

CONCLUSIONS

- Flexible labeling tool
- Data base backend, various posibilities of mining the data
- Easy to use, easy way to led your user train your statistical models in the field
- Reduces problem complexity in heterogenous environments by integrating user interaction

Industrial partners

BOSCH
AMAZONE

References

Bradski, G. 2000. The OpenCV library. Dr. Dobb's Journal 25, 11 (Nov.), 120, pp. 122 - 125.

Boykov, Y., Jolly, M.-P. 2001. *Interactive Graph Cuts for Optimal Boundary & Region Segmentation of Objects in N-D Images*, in: Proceedings of the IEEE International Conference on Computer Vision, Vancouver, S. 105-112. URL: http://ieee.ixploreeee.org/stamp/stamp.jsp?tp=&arnumber=937505&isnumber=20293, 22.03.2013.

Meyer, F. 1992. Color image segmentation. International Conference on Image Processing and its Applications, pp. 303- 306. URL: http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=785528&isnumber=3917 20.03.2013.

Rother, C.; Kolmogorov, V., Blake, A. 2004. *"GrabCut" - Interactive Foreground Extraction using Iterated Graph Cuts*, in: ACM Transactions on Graphics (TOG) - Proceedings of ACM SIGGRAPH 2004, 23(3), pp. 309-314. URL: http://research.microsoft.com/pubs/67890/siggraph04-grabcut.pdf, 15.12.2011.

Ruckelshausen, A., Biber, P., Dorna, M., Gremmes, H., Klose, R., Linz, A., Rahe, F., Resch, R., Thiel, M., Trautz, D. and Weiss, U. 2009. BoniRob – an autonomous field robot platform for individual plant phenotyping, Proceedings of the 7th European Conference on Precision Agriculture, Wageningen Academic Publishers, pp. 841-847.

Acknoledgements

Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz

Bundesanstalt für Landwirtschaft und Ernährung

vCard