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Cost efficient surface condition determination system for sugar beets for a harvester cleaning control using an industrial RGB camera

Vadim Tsukor *[1], Wolfram Strothmann[1], Erik Wunder[1], Witali Schwamm[3], Arno Ruckelshausen [1, 2]

(1. *University of Applied Sciences Osnabrueck, 49076 Osnabrueck, Germany;*

2. *Competence Center of Applied Agricultural Engineering COALA, 49076 Osnabrueck, Germany*

3. Grimme Landmaschinenfabrik GmbH & Co. KG, 49401 Damme, Germany)

Abstract:

This paper focuses on a cost effective and non-destructive sensor system for monitoring the cleaning quality of sugar beets during the harvesting process. As key technology for realizing the sensor based automated cleaning adjustment process system is based on computer vision technology. The whole system is implemented inline on the harvester machine. It is able to determine the ratio of clean, dirty and damaged areas of sugar beets precisely during the harvesting process. As all cleaning parameters on the harvester machine for adjusting the cleaning process are yet set digitally, the developed sensor system – installed inline at the cleaning process - open the opportunity for closed loop control of the entire cleaning process on the harvester. Recently, the authors have demonstrated the feasibility of a hyperspectral imaging system for this measurement task. However, such a spectral system does not fulfill the boundary conditions with respect to cost at the time being. By realizing this task using a standard RGB industrial camera, the technical as well as the commercial barriers can be overcome

Keywords: sugar beet harvester, quality control system, RGB camera, image processing, OpenCV, Robot Operating System (ROS)

1. INTRODUCTION

Operating today's state-of-the-art harvesters on the field is a challenging task. Apart from driving the harvester a variety of operating parameters have to be adjusted respecting the current field situation in order for getting optimal harvesting results relating to the quantity and the quality of the yield. Tools for reducing the complex tasks of the operator for driving the machine during operations on the field, such as automatic steering, were developed and introduced to the market by different machine companies. However, there are still very few systems that assist the operator in selecting the optimal parameter set, e. g. the cleaning settings of a harvester, for the current field situation.

Cleaning parameters of a sugar beet harvester have to be set very carefully. If the cleaning unit is adjusted to aggressive, the sugar beets will be damaged. If it works to lack, the beets will not be cleaned sufficiently. Therefore continuous online monitoring is necessary in order for setting the optimal

Corresponding author: Vadim Tsukor, M.Sc., University of Applied Sciences Osnabrueck. Telephone: +495419693164. Email: *V.Tsukor@hs-osnabrueck.de*

cleaning parameters continuously during a harvesting process on the field. Within the ongoing collaborative research project SmartBot the determination and rating of surface conditions of the harvesting product on the field has been identified as one of the well promising applications for further automation using sensor technology.

In 2012 and -2013 the sensor system for surface condition determination of sugar beets using a NIR hyperspectral imaging system was developed and tested under field conditions [2]. The results had demonstrated, that the used sensor technology has a high potential for the quality control of sugar beets under field conditions. From the side of economic considerations the usage of such NIR sensor systems in the series-production of sugar beet harvesters is currently not possible due to the unit-costs of such sensor at the being.

Since 2013 the cost efficient machine vision sensor system based on a standard RGB industrial camera for monitoring the results of cleaning process on the sugar beet harvester was evaluated and tested under field conditions. This developed sensor system – installed inline at the cleaning process - gives also the opportunity for closed loop control of the entire cleaning process but additionally satisfies the requirement of moderate costs.

2. MATERIAL AND METHODS

The machine vision system consists of five basic components: illumination, optics, camera, computer and software. The developed cost efficient sensor system for surface condition determination of sugar beets is based on the following hardware component and software solutions:

Hardware

As part of a machine vision sensor system the industrial RGB camera “ECO267CVGE67” from SVS VISTEK GmbH with a resolution of 1392 x 1040 pixels, frame rates 25 fps, protection class IP 67 and ETHERNET interface was used. The applied lens Fujinon DF6HA-1B was packed in protective case SVS-Tube-IP67-47-50-AR to protect the optics from affecting dust and water under outdoor conditions. In ordner for reducing the influence of ambient light two 70 W LED spotlight was used. All these component were built into an aluminum frame to be able to use this sensor system on the field mounted into the harvesting machine. An industrial PC for automatic image analysis (image processing) was connected via ETHERNET interface to the camera and was mounted in the driver cab. To realize the human-machine interaction by implementation of algorithms-concept and for visualization of image processing results a display with touch control was additionally mounted in the driver cab

Software solutions

The developed software for sensor system is based on a Linux Ubuntu 12.04 operating system. In addition, two software components were installed - open-source computer vision library OpenCV 2.4.6 [5] version 2.4.6 and Robot Operation System (ROS) Hydro [6]. ROS is a middleware distributed under the terms of the BSD license and consists of different software frameworks, which allow the

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development of commercial and non-commercial software applications.

Figure 1: Grimme Maxtron 620 sugar beet harvester (left), developed sensor system (right)

For field tests the sensor system was mounted into a sugar beet harvester Grimme Maxtron 620 (Fig.1). This harvester offers a variety of adjustments for optimizing the cleaning process during harvesting. As state-of-art for sugar beets quality control and the hence derived cleaning settings have to be adjusted manually by the harvester operator. . The primary objective of the field tests was to determine the ratio of clean, dirty and damaged areas of sugar beets during the harvesting process.

Algorithms

- Algorithm-Concept

To solve this problem of surface determination, various complex algorithms – including detecting and analyzing each single sugar beet – have been developed. However, such algorithms often lead to complex parameter-fields and the need of their special adaptations to the local field conditions. Machine operators, usually are not able to perform this kind of adaptation of algorithm parameters [1]. Therefore, a simpler, parameter-less approach was chosen for this task. It involves human-machine interaction and machine learning but avoids detection of single sugar beets.

The concept of the algorithm is to have the user marking the '*dirty*', '*clean*' and '*damaged*' regions of a few beets in the first incoming example images. This provides a huge up-to-date base of samples for learning pixel-based classification. Afterwards during the process, all pixels of incoming, pre-filtered images are classified using the obtained model and the ratios '*dirty*'/'*clean*' and '*damaged*'/'*clean*' serve as estimators for the cleaning quality.

- Labeling/Training procedure

The advantage of such procedure is that in order for adapting a new situation, the user just have to mark the respective areas of a few beets. This simple task can be performed during operation event by an unexperienced user. An example of an image with a couple of marks sufficient for deriving a pixel

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classifier is given in Figure 2. There clean areas are marked yellow, dirty areas are marked blue, and damaged areas are given by the red marks. The background is marked grey.

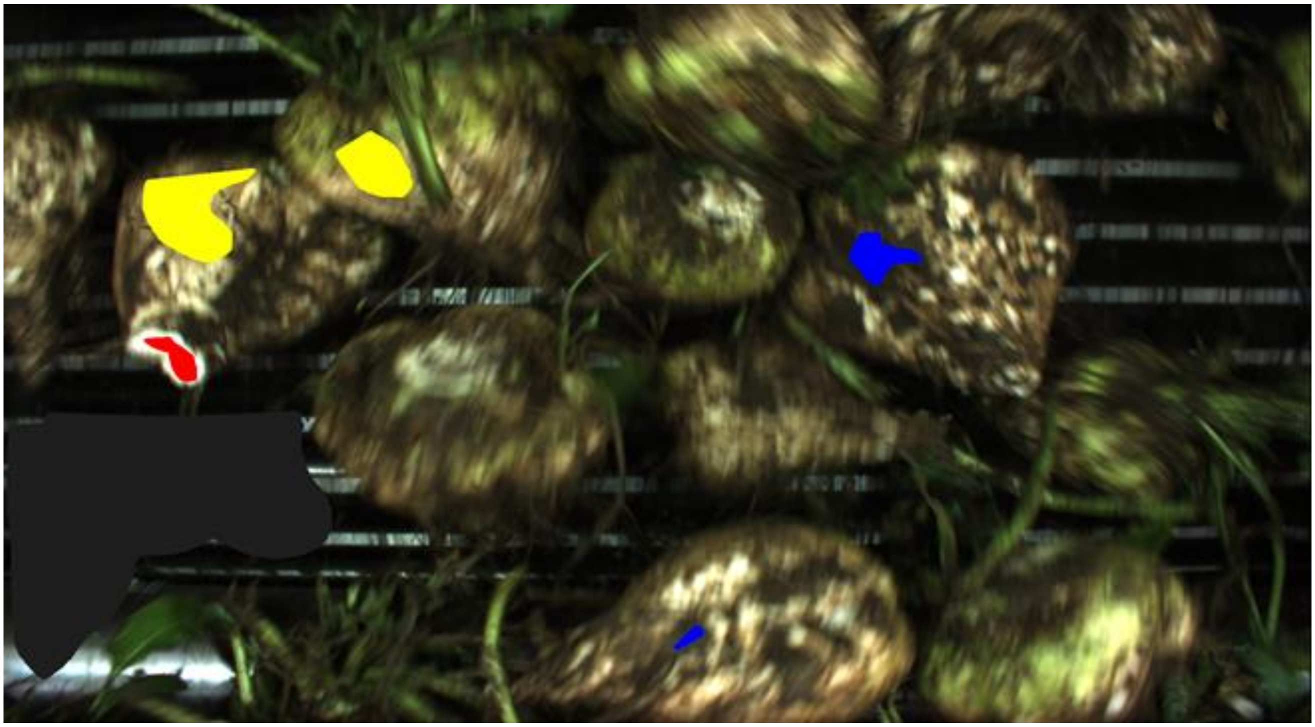

Figure 2: Labeled RGB camera image

The generated label data is stored using a flexible image map framework. It provides multiple back-ends for saving the data in XML or in a PostgreSQL data base including synchronization [1]. In this case the XML back-end is used for storing the data.

- Pre-filtering of machine parts

In order to avoid disturbances of the classification machine parts, such as conveyor bars are filtered out before the main-classification. Regions that possibly could contain conveyor bars are removed, passing only the remaining regions to the classifier. This also reduces the area that has to be classified, thereby reducing the required processing power. An example for an incoming row image is given in Figure 3. In order for filtering conveyor bars the first processing step to be undertaken is applying a threshold to the image (Figure 4a). In the filtered image possible conveyor bars are detected using a hough transformation (Red lines in Figure 4b). Only lines resulting from the hough transformation which appear as a set of lines in the distance of the conveyor web's pitch are able to be identified as conveyor bars. They are marked as green boxes in Figure 4b. In order for avoiding bars which are partly occluded by beets or other objects to pass the bar filtering (e. g center in Figure 4b), the detected bars positions are extrapolated over the entire image respecting the conveyor web's pitch (Blue boxes in Figure 4b).

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Figure 3: Region of interest (ROI)

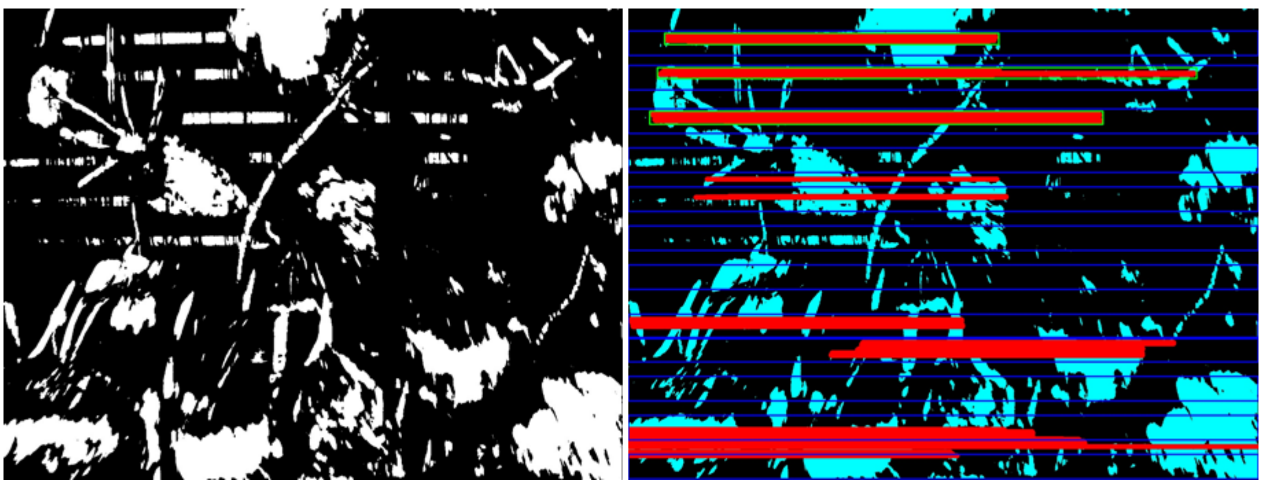

Figure 4: a - Filtered ROI image (left), b – detected conveyor bars (right)

In Figure 5 all regions which could possibly contain conveyor bars are filtered. Of course, there are parts of sugar beets also filtered out. However, for pixel-based classification remaining area still contains a very huge number of snap samples. In case the sugar beets are not detected, it does not matter if the regions are connected or not

- Classification

The remaining areas of the image are classified pixel-based using a Naïve Bayes Classfier [3]. The conditional probabilities needed for each step of the Bayes classification are derived from the color

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channel histograms of the label areas for each label, respecting the color value of the pixel to be classified. Details on the extraction of the conditional probabilities from the histograms can be found in [4].

Figure 5: Filtered ROI image

The result of the pixel-based classification of image above (Figure 5) is given in Figure 6. Regions classified as damaged are marked red, properly cleaned areas are marked yellow and regions marked as dirty are visualized blue. Further examples of fully processed images next to the originals can be found in Figure 7. After the pixels of the image are classified, number of pixels classified into each group can be summed up. The ratios '*dirty*'/'*clean*' and '*damaged*'/'*clean*' can be calculated to quality the cleaning quality. Further the highlighted images as well as a chart of bars indicating the area sizes can be shown to the user.

3. RESULTS

Experiments were performed at outdoor conditions. An algorithm for filtering machine parts in the captured images and classification of the sugar beets' surfaces was developed. To counter the common problem of image processing algorithms to be sensitive to changing ambient conditions, e. g. moisture, ambient lightning a special classification system was designed to be very easily trainable.

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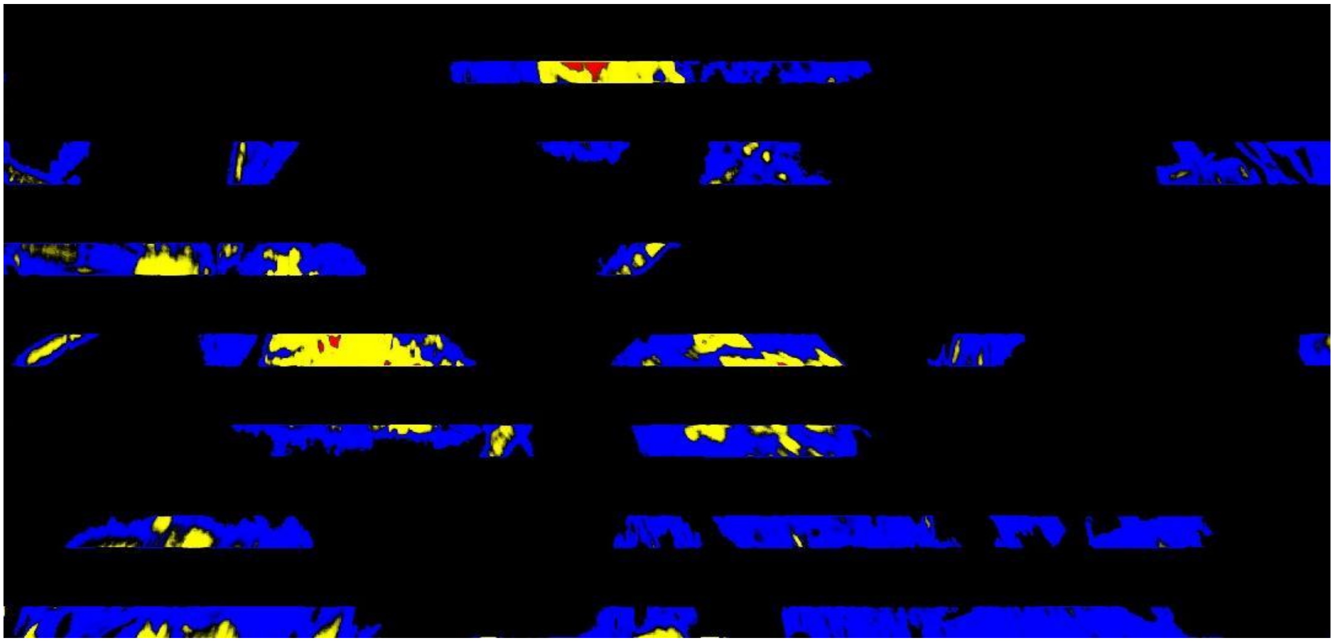

Figure 6: Result of pixel-based classification

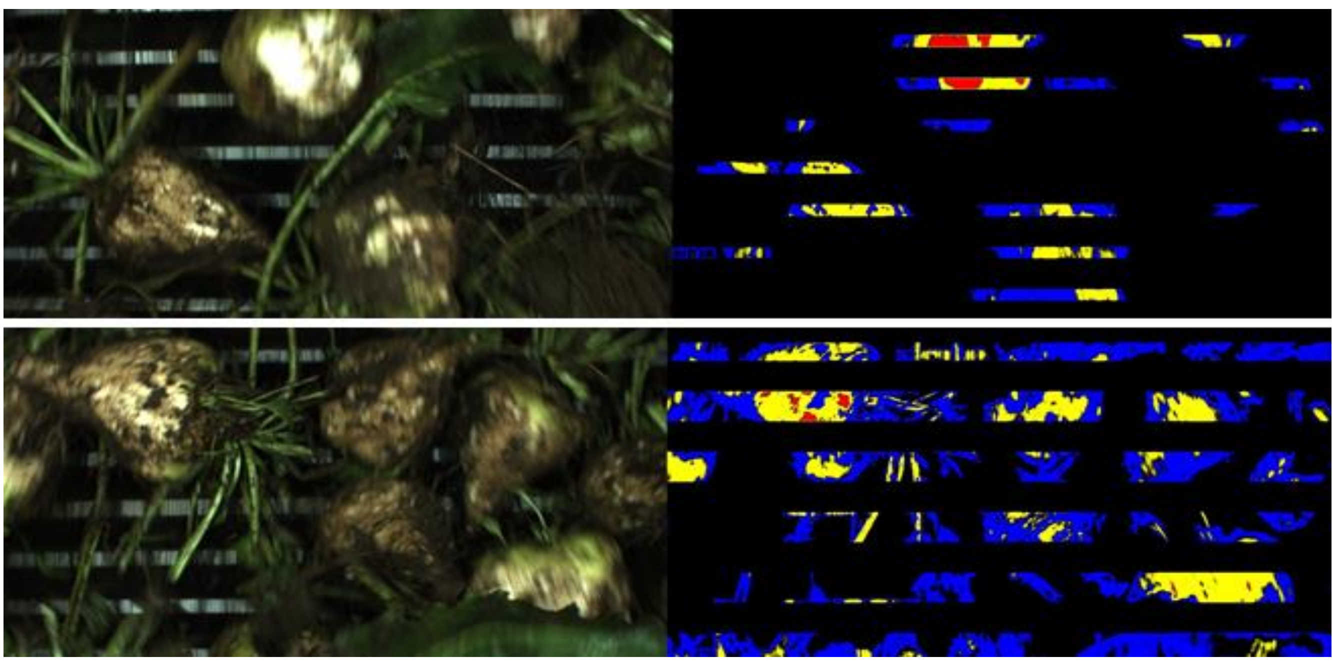

Figure 7: Original RGB camera images and results of Image processing

This allows keeping it up-to-date to the current situation by unexperienced users. It can be trained by just marking small areas of beets in a single captured image as 'clean', 'soil wasted' or 'damaged'. Subsequently captured images are automatically classified. The results are shown the user as bars of areas' sizes in a chart or as highlighted regions in the images. Moreover, the results can be accessed digitally, which allows applying automatic changes of cleaning parameters and closed loop control.

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4. CONCLUSIONS

The developed sensor module has been tested under outdoor field conditions. A method to filter background information, such as machine parts, in the region of interests of the sensor system has been developed. The software allows generating classifications of the sugar beets' surface conditions (healthy, soil wasted, damaged) by human-machine interaction. It can be retrained easily, thereby providing flexibility and robustness against changes of ambient conditions. The results showed, that the developed sensor system has a high potential for the objective of surface classification of sugar beet e.g. for quality control of sugar beet under field conditions to adjust clearing parameters of the harvesting machine.

5. ACKNOWLEGEMENTS

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