VALIDATION OF MODICOVI - MONOCOT AND DICOT COVERAGE RATIO VISION BASED METHOD FOR REAL TIME ESTIMATION OF CANOPY COVERAGE RATIO BETWEEN CEREAL CROPS AND DICOTYLEDON WEEDS

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ABSTRACT

In agriculture, weed control is becoming an increasing problem due to limitations on the amount and on the number of herbicides permitted. This work presents a robust real time and partial occlusion robust method capable of estimating the mono- and dicotyledon leaf coverage ratio within a given imaging area. The developed method (patent P1174DK00) estimates the coverage based on the shape of the vegetation within the image. It does this based on the edge of the segmented vegetation. The detected edges is divided up into a set of equally spaced points where each point is defined by the position of the edge point and the orientation of the gradient where the point was extracted. For each point the relation to the neighboring points (points within a small distance typically ~ 60 mm) are calculated. From the distribution of these relations, a set of descriptors are calculated which describe the shape. A descriptor may for example be an estimation of the average curvature in the image. Preliminary simulated data where the estimated dicotyledon coverage was compared to a set of hand segmented images resulted in an estimation with a standard deviation of 8.9 percentage point. The evaluation was performed on images taken of maize together with natural occurring weeds.

Keywords: soft objects, weeding, occlusion

INTRODUCTION

In agriculture the automation of weed treatment is of high interest as described in (Slaugther, D. et al. 2008). This work relates to the subdomain which the paper defines as machine vision recognition of plant species using biological morphology, to use the shape, registered by a image sensor for the recognition of plant species. This has previously been attempted in numerous papers, whereof some is described in (Slaugther, D. et al. 2008). However generally there is two ways of thought, 1. using a set of morphological features to describe the shape for example as done by Weis, M. et al. 2010 or using a shape model derived from the statistics of recorded images as performed by Søgaard, H. 2005. However both of these methods has problems with partially occluded leaves. The only promising work known to the author in the case of partial occlusion is Kaspersen, K. et al. 2010. The aim of this work is to give a generalized measure of the weed to crop ratio for patches of 50x30cm in real time (delay less than 60ms from beginning of image exposure to activation of nozzle). Another attempt of a real-time vision decision system is described in Burgos-Artizzu, X. P. et al. 2011 where they make the decision based on the amount of vegetation outside of the crop lines.

In this paper we evaluate an algorithm named MoDiCoVi (MOnocot and DIcot Coverage ratio VIsion) which estimates the monocot vs. dicot ratio by analysing the perimeter of the leaves. The scope of the algorithm is limited to the process of how to reach from a segmented (binary) image to a description of the weed pressure. There are numerous papers describing the segmentation process from a raw image ie. (Midtiby, H. et al. 2012).

MATERIALS AND METHODS

Image registration

The dataset used for evaluation was recorded in a field (http://g.co/maps/bchst) at Aarhus University, Faculty of agricultural sciences, Flakkebjerg, Slagelse, at two different stages of development: 1) 2011-06-02 at BCCH 12 and 2) 2011-06-07 at BCCH 13 (The BCCH scale is used according to Hack *et al.*, 1992 and Weber & Bleiholder, 1990).

The images was acquired using two JAI AD-080GE cameras, mounted next to each other in order to cover two rows simultaneously. Images was captured in strips of 1024x128px corresponding to approximately 30x3cm, the strips was captured with approximately 50% overlap. A Trimble 5800 RTK-GPS was used to control the acquisition of the cameras depending on the velocity.

The recording setup was mounted on the three-point hitch of a Fiat 780 tractor using the center frame of a small Hardi NK 6m spraying boom. The recording area was covered with a white tarpaulin to cause diffused lighting. The images were then stitched together by estimating the homographies between adjacent images using SIFT features. The images was then segmented as described in (Midtiby *et al.* 2012).

Fig 1. Image showing the recording setup in the maize field. The sub image in the upper left corner shows the two cameras in sealed housings under the white cover

Image processing

The MoDiCoVi algorithm takes a segmented image as input and gives a percentage describing how many pixels of the frame was weed pixels.
The algorithm consists of a number of stages

1. Find directional edges
2. Reduction of edge points
3. Find relative measures between edge points
4. Use a gaussian mixture models inspired framework for estimating coverage

Find directional edges

For finding the directional edges we use a first order symmetry derivative filter(Bigun, J., 2006, chapter 10).

$$\Gamma\{p,\sigma^2\} = (D_x + iD_y)^p \frac{1}{2\pi\sigma^2} exp(\frac{-x^2-y^2}{2\sigma^2})$$

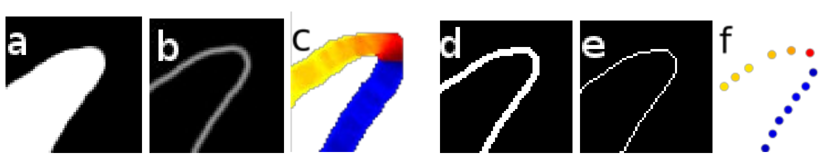

Fig 2. a:Input image, b:magnitude after convolution with symmetry kernel, c:Phase after convolution with symmetry kernel, d:Magnitude after threshold, e:skeletonized version of d. f: subsampled combination of c & e

As a result of the convolution we have the magnitude and phase response (Fig 2. b/c). As the phase directly corresponds to the absolute orientation, at the maximum magnitude. Thresholding is performed of the magnitude(fig 2.d) followed by skeletonization(fig 2.e). The skeletonized image can then be applied as a mask to select where to sample the phase.

Reduction of edge points

Reduction of the edge points is done by using the median value within a sparse grid of 8x8 pixels. The reduction is done in order to reduce the probability of outliers as well as to reduce the amount of data for further processing. An example of the results of the resampling process can be seen in fig. 2.f.

Finding relative measures

In order to achieve a rotation and position invariant representation we define a metric which describes the relation between the neighboring edge points. This is performed by superimposing a coordinate system along a point of reference as shown in fig. 3.

The origo of the coordinate system is placed in the center of the reference point, with the x-axis pointing along the edge and the y-axis pointing towards the foreground ("onto the edge").

Using this coordinate system to describe the relation between the reference point and a neighboring point we measure the neighboring point's position in the local coordinate frame as well as the relative orientation compared to the reference point.

We define neighboring points as points which lies closer than 125px from the reference point.

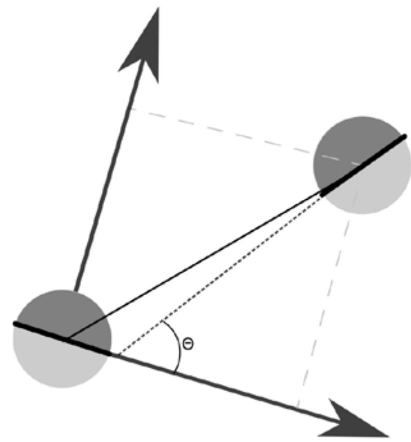

Fig. 3. Superimposed coordinate system describing the relationship between two neighboring points.

Estimating dicotyledon / monocotyledon coverage ratio

In order to estimate the coverage ratio we analyse the population of relative measures (see figure 4). The analysis is performed in a manner inspired by gaussian mixture models in the way that we consider the population to be multimodal and try to estimate it by a set of unimodal models each with a normal distribution.

Each unimodal population is described in a 3-dimensional space consisting of distance along the edge(x), distance across the edge(y) and the difference in angle.

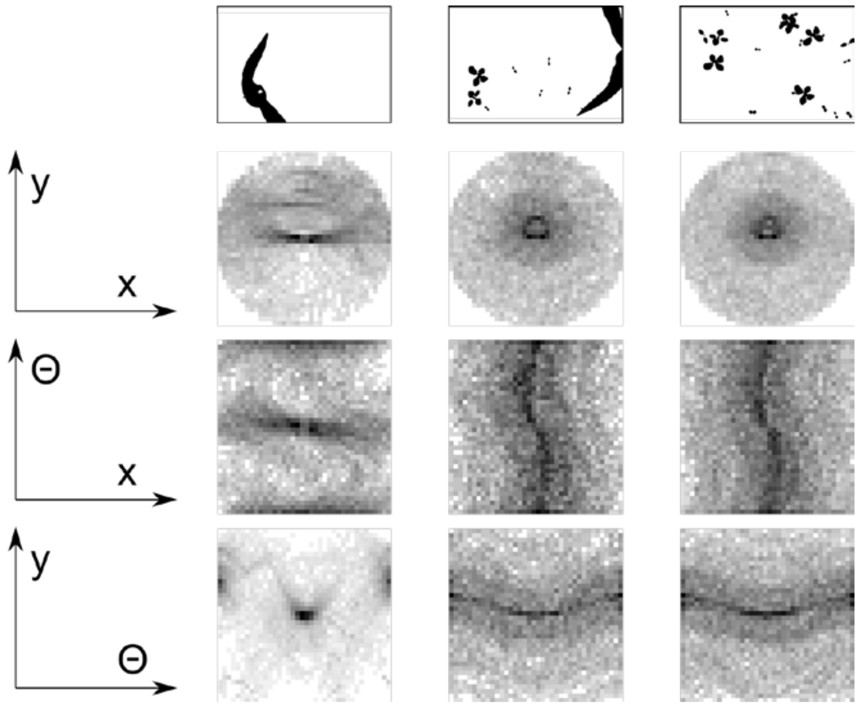

Fig. 4. 2D projections of populations from a three-dimensional space consisting of x,y and distance of angle.

Each gaussian is described with a mean value and a deviation describing each estimate of the normal distribution.

In order to give an estimate of the weed pressure each of the unimodal population estimates is then combined into a weighted sum.

Generation of training set

In order to estimate the weights, widths and position of the gaussians we create a training set. The training set is created artificially as it is very cumbersome to manually annotate large amounts of data. A simulator is created and receives a set of segmented images of each class, then for each image to be created a random amount of images from each class is selected and inserted into the image at random positions and orientations.

Regression analysis

In order to determine the model describing the position and deviation of the gaussians a large training set is created as described above. Then a set of 6000 gaussians is created at random positions and widths. For each of these gaussians their correlation with the weed density is measured. This allows us to extract the 16 gaussians with the highest correlation. These 16 gaussians is then weighted in order to achieve the highest combined correlation with the weed density.

RESULTS

Statistics of the algorithm was performed using a simulated dataset of 300 images which resulted in the residuals shown in figure 5

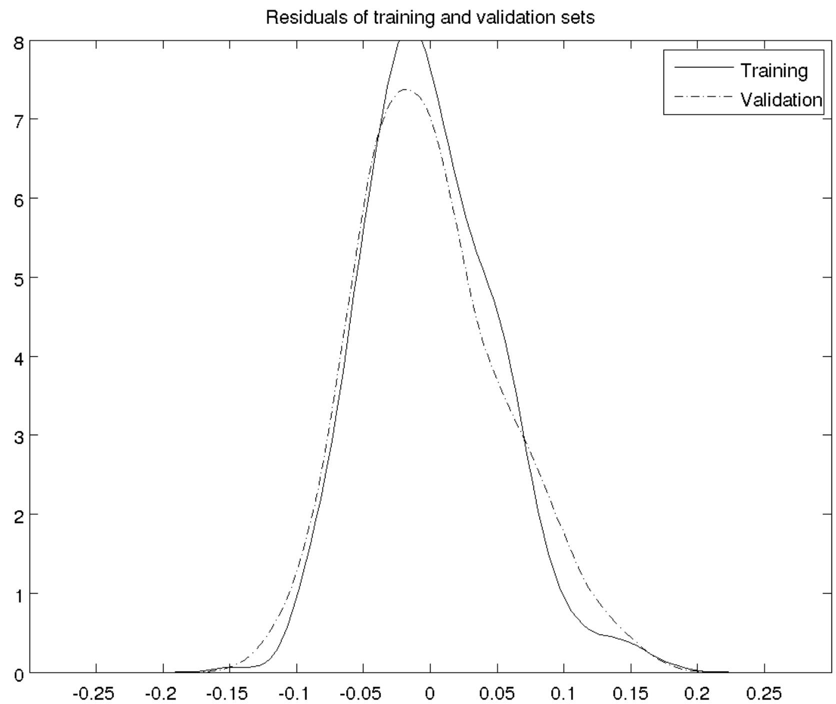

Fig. 5. Residuals of simulated images

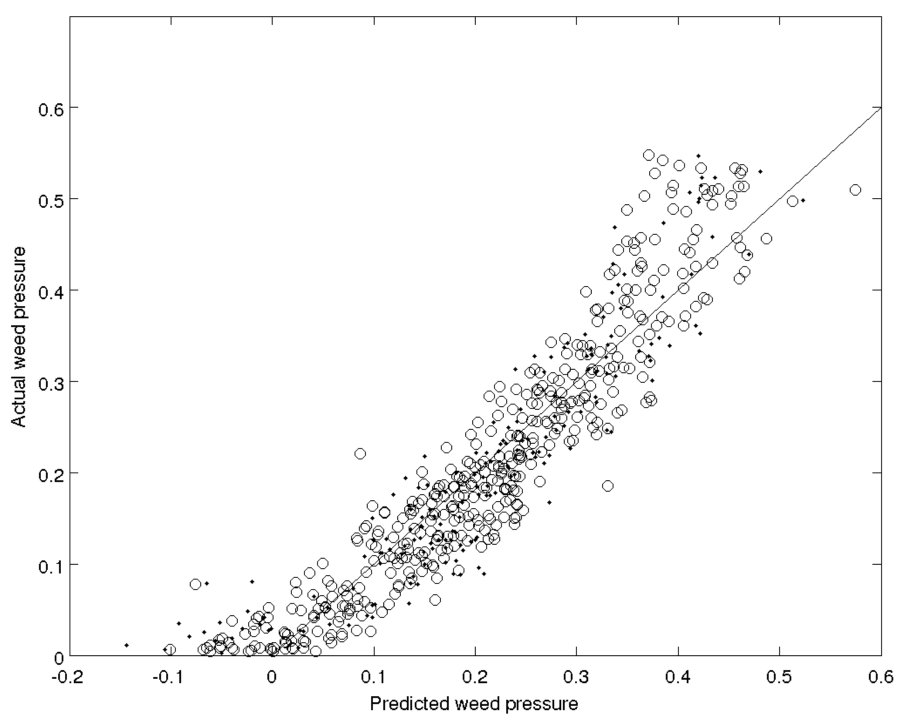

Fig. 6. Predicted compared to actual weed pressure for training and validation data

Furthermore the performance of the algorithm was verified on a set of real world images to verify credibility of the results based on the simulated dataset.

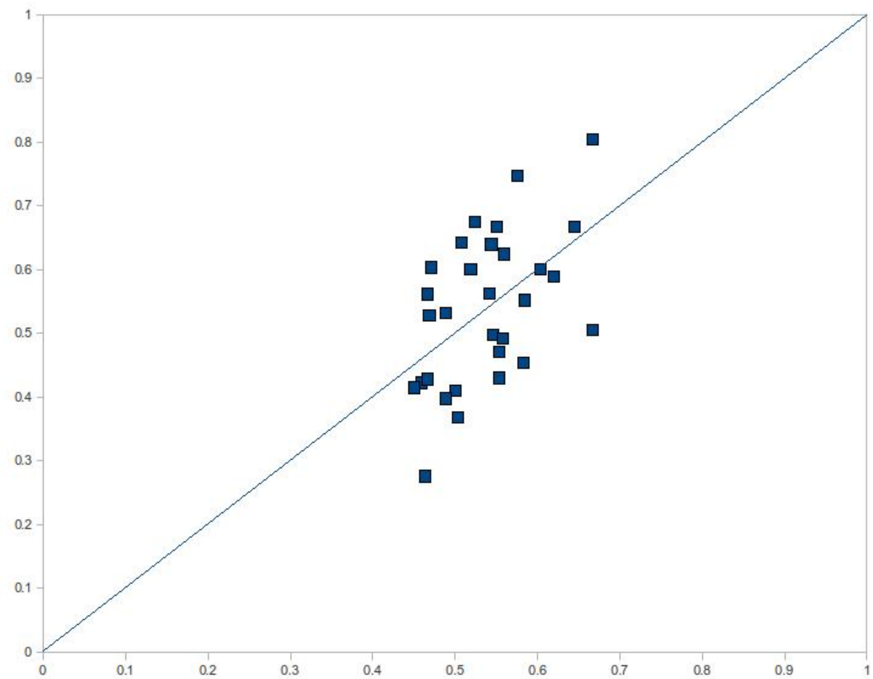

Fig. 7 Predicted compared to actual weed pressure for real world images

DISCUSSION

The current edge detection does not generate edges between overlapping leaves but only where the leaves overlap non-vegetative subjects. This causes problems under very heavy occlusion as the estimate in such cases is based on very sparse measurements.

As can be seen from the statistics the performance is mediocre at best, however looking at the histograms it seems that the information is present. What may however be part of the fault is the assumption that a gaussian is a good model of the distribution.

CONCLUSION

This paper presents the results for the current implementation of the MoDiCoVi algorithm. Performance is not yet up to par with existing algorithms working under non-occluded conditions. However from the population densities it seems that more information may be extracted, by rethinking the regression analysis.

FUTURE WORKS

In order to improve the performance of the algorithm it may be of interest to look into performing transformation from the x,y,theta into another representation. One example of such a representation could be a measure of curvature defined using the osculating circle.
Another improvement for highly occluded regions would be improvements of the edge detector when two leaves overlap.

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