Crop Row Benchmark Dataset

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1. Benchmark Dataset Overview

Crop Row Benchmark Dataset (CRBD) can be used for evaluation of crop row detection methods. The dataset contains the following files:

- crop row images,
- ground truth data,
- Matlab function for creating ground truth image,
- Matlab function for evaluation of crop row detection methods,
- results of TMGEM (Template Matching followed by Global Energy Minimization) method [1],
- Matlab demo script which evaluates the results of TMGEM method.

File names, folder names and file count are given in Table 1, where [%3d] represents three digit integer number from the interval [1, count].

Table 1. Files and folders in CRBD.

File name	Folder	Count
crop_row_[%3d].jpg	Images	281
imageClassification.txt	Images	1
imageClassificationTMGEM.txt	Images	1
crop_row_[%3d].crp	GT data	281
createGTImage.m	root	1
crop_row_[%3d].tmg	TMGEM results	281
CRDA.m	root	1
CRDA_demo.m	root	1

A detailed explanation of all files is given in the following sections. Section 2 describes the crop row images and gives their classification. The ground truth data representation is described in Section 3. Matlab function for creating a crop row ground truth image according to the ground truth data is explained in Section 4. Section 5 gives an

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explanation of Matlab function for evaluation of crop row detection methods. The results of the TMGEM method and a demo script which evaluates these results are described in Section 6.

2. Test Images

Images folder contains crop row images of different types like maize, celery, potato, onion, sunflower and soya bean. Different amount of weed and shadow occur in the captured images. On some images, grass, sky or road appears. Furthermore, the images are taken at moderately varying yaw, pitch and roll angles. The images were acquired with a Panasonic LUMIX DMC-F2 digital camera during the spring of 2014 in Croatian region Slavonia. The images are originally captured at a resolution of 2560 x 1920 pixels and resized to 320 x 240 pixels. This subsampling reduces the required computation time without significant loss of information. The complete evaluation image set contains 281 images and each image is named *crop_row_[%3d].jpg*, where [%3d] represents three digit integer number from the interval [1, 281]. An example of a crop row image is shown in Fig. 1.

Fig. 1. A sample image of crop rows.

The images are divided into two subsets, a subset with straight crop rows containing 48 images (image set 1) and a subset with curved crop rows containing 233 images (image set 2). For classification of the images please refer to *imageClassification.txt* document included in CRBD, where each image is assigned the number of the image set it belongs to.

In [1], the original image set is subdivided into training set and test set. The training set, which contains 56 images (20% of the total of 281 images) is used for determining the appropriate values of crop template parameters. The test set, which contains the remaining 225 images, is used for evaluation of the proposed method. Furthermore, the test set is divided into two subsets, a subset with straight crop rows containing 34 images (image set 1) and subset with curved crop rows containing 191 images (image set 2). For this classification of the images please refer to *imageClassificationTMGEM.txt* document included in CRBD, where each image Is assigned the number of the image set it belongs to. The number 0, in classification document, means that the corresponding image belongs to the training set.

3. Ground Truth Data

Ground truth data is created manually for each test image using application developed and described in [1]. The ground truth data for a test image represents a sequence of values of the ground truth crop parameters. These parameters are the distance between crop rows, denoted in Fig. 2 by d_v^* and the position of the central crop row relative to the image center, denoted in Fig. 2 by c_v^*, where v represents the index of the considered image row. In some of the considered test images, crop rows are not visible in few top image rows because of the perspective effects or in the cases where sky appears in the top of the image. Therefore, the ground truth curves are defined from a particular image row v_0 to the bottom of the image.

There are 281 ground truth data files in *GT data* folder and each of them is named *crop_row_[%3d].crp*, where [%3d] represents three digit integer number from the interval [1, 281]. The ground truth data files can be opened with any text editor such as Notepad or Notepad++.

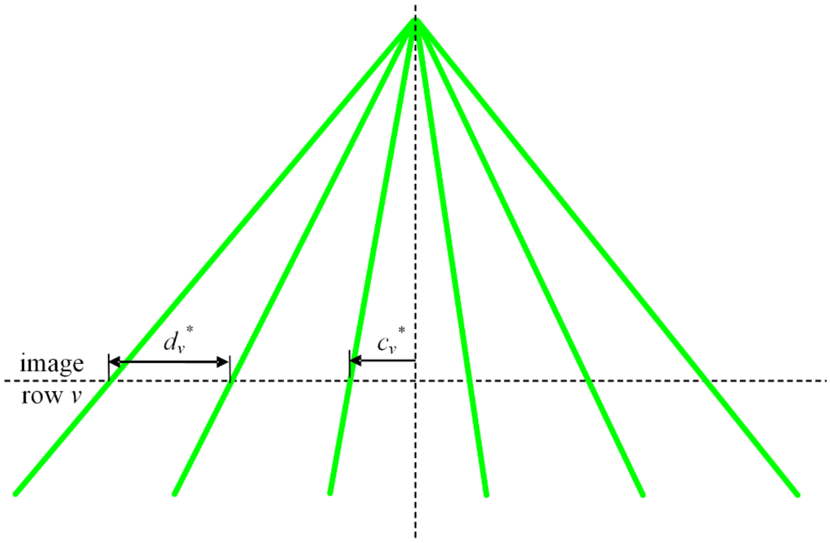

Fig. 2. The crop parameters assigned to each image row. Crop rows are depicted in green.

4. Creating Ground Truth Image

For each CRBD image, a ground truth image can be created according to the ground truth data described in Section 3. The ground truth image can be created using Matlab function *createGTImage.m* which is included in CRBD. The function has the following inputs:

- *imageName* – the name of the image for which a crop row ground truth image is created. Ground truth data for the image must be named [imageName].crp.
- *showSaveFlag* (optional) – flag for displaying and/or saving the created crop row ground truth image. If this flag is not set, the function returns the created image but it does not display the image and does not save it. Valid values for the parameter are 1, 2 and 3. According to the set value, the function does the following:
    - 1 – displays the created image,
    - 2 – saves the created image,
    - 3 – displays and saves the created image.
- *imagePath* (optional) – absolute path to the image folder if it is not in the same folder as the function.
- *GTDataPath* (optional) – absolute path to the ground truth data if it is not in the same folder as the function.

The output of the function is a crop row ground truth image. Due to three optional parameters, the function for creating ground truth images can be called by the following syntax:

```
GTImage = createGTImage(imageName, showSaveFlag, imagePath, GTDataPath);
GTImage = createGTImage(imageName, showSaveFlag, imagePath);
GTImage = createGTImage(imageName, showSaveFlag);
GTImage = createGTImage(imageName)
```

An example of the ground truth crop row image created for one of the test images is shown in Fig. 3.

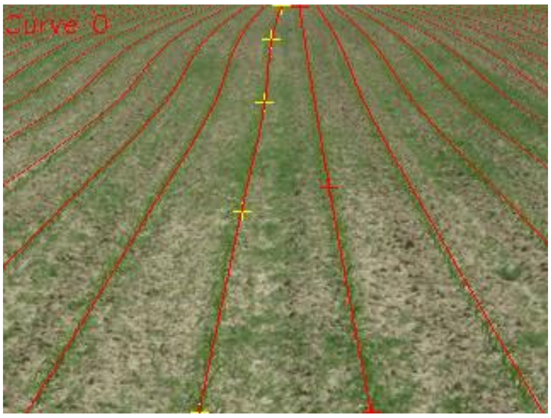

Fig. 3. Example of ground truth crop rows.

5. Evaluation of Crop Row Detection Methods

Evaluation of the considered crop row detection methods can be performed by comparing the results obtained by these methods with the ground truth. Therefore, an output of each of the considered methods is represented by a matrix whose number of rows corresponds to the number of image rows *h* and each row of the matrix has *m* elements, $u_{v,1}$, $u_{v,2}$, …, $u_{v,m}$, representing the horizontal coordinates of *m* adjacent crop rows detected by the considered method in the *v*-th image row. The ground truth can be represented analogously, i.e. by *m* values, $u^*_{v,2}$, …, $u^*_{v,m}$ computed from the parameters c^*_v and d^*_v.

In [1] a suitable crop row detection performance measure is designed which we named Crop Row Detection Accuracy (CRDA). CRDA is defined as

$$CRDA = \frac{1}{m(h-v_0)} \sum_{v=v_0}^{h-1} \sum_{i=1}^{m} s\left(u^*_{v,i}, u_{v,i}, d^*_v\right), \quad (1)$$

where

$$s\left(u^*, u, d\right) = \max\left(1 - \left(\frac{u^* - u}{\sigma d}\right)^2, 0\right), \quad (2)$$

and σ is a user defined parameter.

The matching score (2) is greater than zero only if the horizontal distance between a detected crop row and the corresponding ground truth curve is less than $\sigma \cdot 100\%$ of the distance between adjacent crop rows. In general, value σ depends on a desired accuracy needed for safe guidance of an agricultural machine.

CRDA calculation can be performed using Matlab function *CRDA.m* which is included in CRBD. The function has following inputs:

- U - matrix of dimensions h x m, where h represents the number of image rows and m represents the number of crop rows to be evaluated. Elements of each matrix row $u_{v,1}$, $u_{v,2}$, …, $u_{v,m}$ represent the horizontal coordinates of m adjacent crop rows detected by the considered method in the v-th image row.
- *GT_CRP* - Ground Truth Crop Row Parameters. Matrix of dimensions $(h - v_0) \times 2$, where v_0 represents the first image row with visible crop rows. Each matrix row contains crop row parameters c_v^* and d_v^* where c_v^* represents position of the central crop row relative to the image center and d_v^* represents distance between crop rows in the v-th image row.
- m (optional) - the number of crop rows to be evaluated. The default value is 3. Must be an odd number.
- *sigma* (optional) - the desired accuracy needed for safe guidance of an agricultural machine. The default value is 0.1, which means that the matching score is greater than zero only if the horizontal distance between a detected crop row and the corresponding ground truth curve is less than 10% of the distance between adjacent crop rows.
- *adjacentGTRows* (optional) - the ground truth values are generated for multiple groups of m adjacent crop rows and CRDA is computed for each group. The total number of adjacent crop rows in all groups is specified by the parameter *adjacentGTRows*. Therefore, the number of groups is $n = adjacentGTRows - m + 1$. The maximum of n obtained CRDA values is considered as the final performance measure for a particular image. The default value is 9.

The output of the function is CRDA value which represents Crop Row Detection Accuracy defined by (1). Due to three optional parameters, the function for calculation of CRDA value can be called by the following syntax:

```
CRDA_value = CRDA(U, GT_CRP, m, sigma, adjacentGTRows);
CRDA_value = CRDA(U, GT_CRP, m, sigma);
CRDA_value = CRDA(U, GT_CRP, m);
CRDA_value = CRDA(U, GT_CRP);
```

6. TMGEM Method Evaluation

Usage of the CRDA function is demonstrated by a Matlab demo script *CRDA_demo.m* included in CRBD. This script demonstrates calculation of CRDA for the TMGEM method.

The results of the TMGEM method are stored in the *TMGEM results* folder. For each test image results are stored in a file named *crop_row_[%3d].tmg*, where [%3d] represents a three digit integer number from the interval [1, 281]. The files can be opened with any text editor such as Notepad or Notepad++. The results for each test image are represented by a matrix whose number of rows corresponds to the number of image rows h and each row of the matrix has m elements, $u_{v,1}$, $u_{v,2}, \ldots, u_{v,m}$, representing the horizontal coordinates of m adjacent crop rows detected by the TMGEM method in the v-th image row. The values of parameters h and m are 240 and 3, respectively.

In the discussed demo application, the CRDA value is calculated for all 281 test images with *sigma*, *adjacentGTRows* and *m* set to 0.1, 9 and 3, respectively. The parameters *startImg* and *endImg* enable a user to select different subsets of test images. The output of the application is an array of CRDA values and normalized cumulative histogram[2] of CRDA for all tested images.

If you want to evaluate your own crop row detection method, the results of the method should be stored in the same form like the results of TMGEM method. The extension of the files and the folder can be different. The parameters *results_folder* and *extension* should be set to appropriate values. If you have any questions regarding the Crop Row Benchmark Dataset or its usage, please send it in an e-mail to the following address: ivan.vidovic2@etfos.hr.

References

[1] I. Vidović, R. Cupec and Ž. Hocenski, "Crop Row Detection by Global Energy Minimization," *Pattern Recognition,* vol. 55, pp. 68-86, 2016.

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[2] A normalized cumulative histogram is a data representation where the horizontal axis corresponds to values of a measured variable x and the vertical axis represents the percentage of measurements which are $>= x$.