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Camera-based control system of a mechanical hoe for sugar beets

Mechanical weed control is currently limited to application in organic agriculture. Technically, intra-row weed control is problematic and still requires a high amount of manual labour. The aim of the project presented here is to design a mechanical hoe for intra-row weed control. For this purpose a camera-based control system was developed that determines the position of the plant in real-time and controls the hydraulically-driven implement in accordance to the position of the next plant. Consequently, it is possible to determine the exact position of the plant, from the picture that is taken by the camera, in real-time and independently of the speed within stage of development BBCH 10 to BBHC 14 of the sugar beet.

Keywords
Intra-row weed control, sugar beet cultivation, image processing, CCD-camera

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In applying herbicides, not only the efficacy but also the impact on human health, groundwater, the environment and the possibility of mitigating these negative impacts are considered [1; 2; 3]. Mechanical inter-row weed control in sugar beet production is technically solved and provides outstanding results. With these implements the field can be worked up to 5 cm close to the row of sugar beet plants. Consequently, there is still a strip close to the plant that is not worked. But, especially the weed that grows here, close to the plants, can impede the growth of the sugar beet plants in their early growth stages. This competition between sugar beet plants and weed for growth factors can lead to significant yield losses. Currently, weed control within plant rows in the early growth stage is only possible with high input of manual labour. Our own field trials of mechanical weed control in organic farming have shown that a combined use of machines working the intra and inter row area is efficient. Thereby, the manual labour input for weed control can be reduced. **Table 1** presents values for the respective manual labour needs for intra-row weed control of different crops. Due to their predefined distance, trans-planted crops are easier to be controlled of weeds than directly sown plants.

For an additional reduction of manual labour without damaging the crop plants, mechanical intra-row weed control is necessary. The aim of the present project is to develop a selective working hoe that removes the weed within rows of crop plants. At the beginning of the project the system requirements were elaborated. The most important requirements are:

- real time detection of the next plant's position,
- driving and working velocity ≥ 1 m/s,
- theoretical seed plant position is adjustable between 14 cm and 20 cm,
- low losses of cultivated plants.

Table 1

Manpower hours per hectare [Mph/ha] required for manual labour in different crops in the Netherlands and Switzerland

Kulturpflanze *Crop*	Aussaatverfahren *Planting method*	AKh/ha *Mph/ha*
Zuckerrüben *Sugar beet*	Gesät *Sown* [1]	82
	Gesät *Sown* [4]	134
	Gepflanzt *Planted* [1]	28
Zwiebel *Onion*	Gesät *Sown* [1]	177
Karotten *Carrot*	Gesät *Sown* [1]	152
Gemüse *Vegetable*	Gepflanzt *Planted* [1]	46

Image recording

Hoeing exclusively the spacing between the plants makes it necessary to detect the exact position of each sugar plant in order to steer the hoe accordingly. This position detection makes is possible to balance the slip at the driven wheel of the precision seeder which can lead to variations in the seed placement, and also to balance the slip appearing at the hoe wheel. Consequently, it is possible to carry out intra-row weed control for varying plant spacing. For this purpose a special image processing software was developed, which sends a correcting signal to the control cycle of the hoe and thus either accelerates or slows down the continuously working implement accordingly. For working the spacing between the plants two hydraulically powered implements are available.

In a first step an image is taken by the CCD camera with a daylight cut filter. The camera does not take pictures continuously but is triggered at a specific point of the implement rotation. Light within the near-infrared range with a wavelength of 800nm or above is reflected up to 50%. Light within the visible wavelength range is absorbed by chlorophyll and other particles [5]. Due to this reason a daylight cut filter is used that filters wavelengths below 780nm. The generated grey-level image provides a high contrast between the plants and the soil. Due to the processing of the image it is not necessary that the image is taken with a defined exposure. Shadow casts can be balanced but very strong and fast changing lighting conditions can still influence the plant detection negatively.

Real time detection of the positions of sugar beet plants

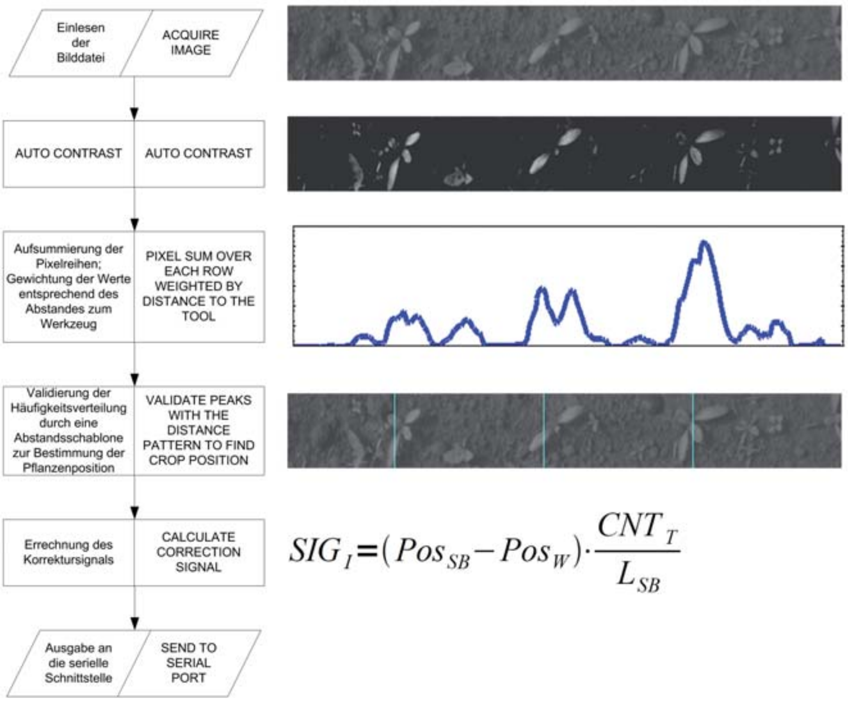
Figure 1 shows a grey-level image taken by the CCD camera. The software reads the picture and spreads its optimally in order to differentiate the plant matter from the ground. The contrast stretching is undertaken for each image individually depending on the brightness of the image. Continuously happening shadow cast is compensated by a further processing step.

Fig. 1

Grey level image before (above) and after the contrast spread (below)

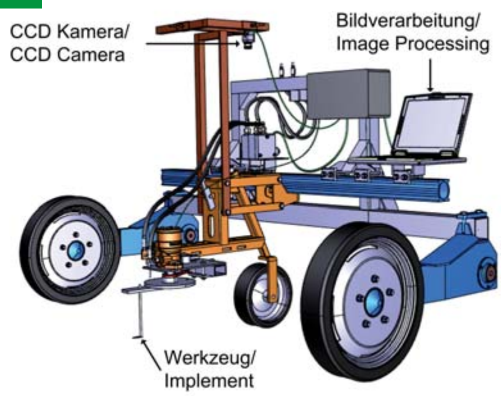
The frequency distribution of plant matter in the picture forms the basis of the real time detection of the plants. The individual steps in this process are shown in **figure 2**. After reading the image and stretching the contrast of the image, it is converted into a one-dimensional data series by summing up the pixel-rows in the grey-level image. Then, these values are weighted according to the distance to the implement. Thereby a better adjustment of the implement to the spacing between the plants is guaranteed. In a next step the plants that are detected with the frequency distribution are validated with a spacer which is consistent with the theoretical spacing between the plants. The estimated distance between the first plant and the image edge is used as calculation basis for the correcting signal, which is then transmitted to the hoe control. The estimation of the distance is carried out in real-time. The average processing time is 30 ms with the used 2 GHz processor.

Fig. 2



Schematic design of image processing

Fig. 3



Schematic design of the hoe for mechanical intra-row weed control

Conclusions

A field trial of plant position detection in a sugar beet field with plant distances of 14 cm had a position detection rate of 90 %. Therefore, it can be concluded that the integration of the camera-based control system in a single-row prototype for mechanical intra-row weed control (**figure 3**) allows an effective, plant protecting mechanical weed control between plants. First field trials have proven the functionality of the hoe prototype. The requirements for the system regarding the working velocity and plant protection can be fulfilled.

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