Weed control in short rotation coppices with a GPS-assisted field robot

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Abstract: Mechanical weed control is very important during the establishment stage of short rotation coppices. GPS-assisted field robots can help to increase the labour efficiency of mechanical weeding. The basic requirement for an autonomous weeding robot is the information about the accurate position of the trees. The low planting densities and well defined planting spots are in favour of identifying the trees. But the high weed densities on the other hand make a distinction between crop and weed difficult. Under these high weed conditions image based systems proved not useful for the individual plant recognition. The presented work therefore uses a different approach using inductive detection of metal marks which have been applied to the planting material. The functionality of this inductive recognition system was tested under the specific conditions in short rotation coppices plantations.

1 INTRODUCTION

The sustainable provision of biomass as a renewable source of energy is a common task for European agriculture. The cultivation of fast growing tree species (willow, poplar) as short rotation coppice (SRC) is an economically and ecologically interesting alternative. To date the acreage of SRC in Germany is about 6000 ha. In order to extend the usage more efficient methods of cultivation, harvesting and storage of the woodchips are required (Ehlert et al. 2013, Pecenka et al 2014).
SRC plantations are typically established by planting cuttings with row distances between 2 and 3 m at planting distances from 0.3 to 0.5 m in the spring. Special planting equipment is used to guarantee a high accuracy of row and planting distances. Between the rows it is possible to reduce weed by mechanical tillage or by the use of a mulcher. In the row weeds often have to be removed by hand which is very labor intensive especially at fields sizes of typically 3 ha and more.
During the establishment stage of the short rotation coppice, that is the first year after planting, the trees are in strong competition for nutrients, water and light with other plants. High weed population may lead to delays in growth, decrease in yield or extensive failures. For this reason in the first year weed control is very important.

2 WEED CONTROL

Chemical weed control: during the first 5 - 6 weeks after planting, the emergence of weeds can be prevented by applying pre-emergent herbicides. Post-emergent herbicides have been tested for selective weed control in plantations of poplar and willow. It was possible to eliminate a few species of weeds. On the other hand it turned out that many herbicides damaged the young trees (Seidl at al 2013). For this reason mechanical weeding is preferred for the later cultivation stages of SCR.
Mechanical weed control: In order to reduce the application of pesticides, autonomous systems gain importance in modern weed control. Especially for SRC with their low planting densities and well defined planting spots GPS-assisted field robots could increase the labor efficiency. A basic requirement for the use of robots in SRC is the information about the accurate position of the planting spot within the row. Using this position data an autonomous system could cultivate the area around the tree to keep it clean from weeds. Therefore the presented work focuses on the development of a sensor system to detect the cutting in the planting spots for mechanical weed control in SRC plantations.

3 CURRENT RESEARCH

Autonomous weeding equipment for horticultural machines has been developed for row crop like lettuce. These machines typically use camera systems analyzing the images taken in front of the device to identify the plants. Based on the information of color and size the software decides between lettuce and weeds (Garford 2014).
Other plant recognition systems add the 3rd dimension, the depth information to the images, by installing time of flight cameras or laser scanners (Li 2014, IPA 2015).
In another research project the individual plant recognition occurs with a combination of several simple sensors. Central to this is a sensor for the height profile. It consists of a set of light barriers and submits a side profile of the planted rows to the system. This side profile can give a precise indication of the individual plants (Kielhorn 2000).

But imaging Sensors with wavelength in the range of visible light and near-infrared light did not prove successful to detect the trees in the SCR plantation under all circumstances. Compared with the competing weeds, the planted cuttings develop very slowly during the first weeks. Often the young trees are overgrown and covered by the weed plants. The binary images developed from infrared images taken at the ATB's plantation illustrate this (Figure 1 and 2).The trees could only be clearly identified at low weed densities. In areas with more and lager weed plants even with the human eyes it is almost impossible to recognize the cultivated plants.

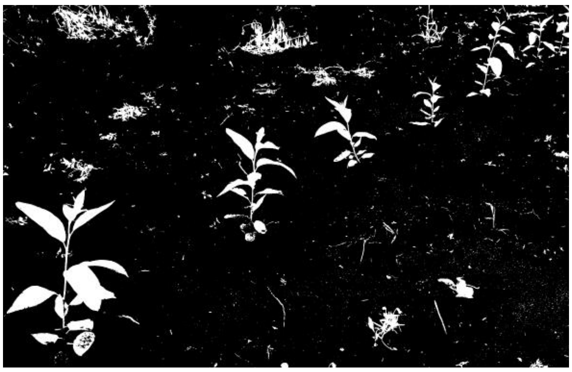
Figure 1: Binary images of the SRC at low weed density.

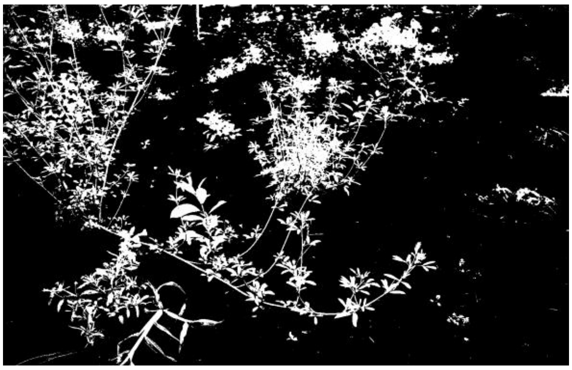
Figure 2: Binary images of the SRC at high weed density.

Image analysis as a method for the detection of the planting spots respectively the trees seems too difficult under high density weed conditions in SRC plantations. Alternative technologies have to be researched. Preliminary tests with capacitive measurements of trees and weeds did not show any differences between the species, just between the different sizes of plants and where therefore not prolonged.
Promising results were achieved with the detection of marked cuttings by an inductive sensor. Therefore a strategy to detect marked cuttings using a metal detection sensor has been investigated in an experiment at different weed densities.

4 MATERIAL AND METHODS

An individual plant recognition system in SRC should enable autonomous weed control in the area around the trees, getting as close to the trees as possible without killing the crop. Therefore the position of the cutting needs to be detected with high precision.
The detection range, accuracy and repeatability of marked cuttings by a metal detection sensor have been investigated in an experiment. The test setup was designed and built up to identify detection ranges between the sensor head and the cutting under distinct weed densities and different iron markers (Figure 4).
The main components of the setup are the *metal sensor* attached to the *linear actuator* to move the metal sensor across the *test field*, a *draw wire sensor* for referencing the linear position, plus a *microcontroller* to evaluate the signals.
To detect the planting material with the metal sensor every cutting was marked with a staple of the type C 6/18. The staples are made of iron with weights of

0.25 g per piece. The test field was populated with young trees -grown from the cuttings- and weeds. The metal sensor is a SURF PI 1.2 sold by the company SILVERDOG. The detection method is based on the pulse-induction-system. The block wiring diagram in figure 3 illustrates the functionality of pulse-induction sensors.

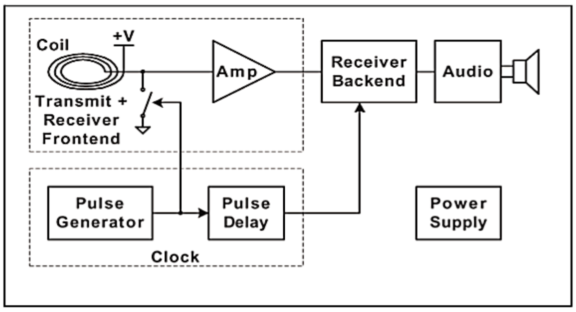

Figure 3: Function of pulse-induction sensors

For each test run the linear actuator was extended to move the metal sensor across the test field. By that the metal sensor approaches a marked cutting with the metal staple. When the coil in the sensor head approaches a metal staple the microcontroller records a change in the metal detector signal. As soon as the signal fulfills the criteria defined by the tests, the recognition system assumes that there is a poplar tee in front of the sensor head and stops the movement.

In order to evaluate the repeatability and accuracy of the detection range, the linear position of the sensor head has been measured by a draw wire sensor. Its signal is also used for the position control of the linear actuator by the microcontroller. After a successful detection, using the linear actuator, the sensor head with the coil moves back to the starting point and the next measuring process can start.
The sensor system has been investigated in two test fields with different weed densities and three different decision criteria for tree identification.

5 RESULTS

An exemplary detection signal is shown in Figure 5.

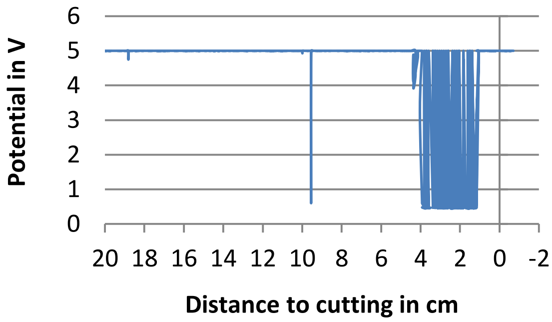

Figure 5: Sensor signal

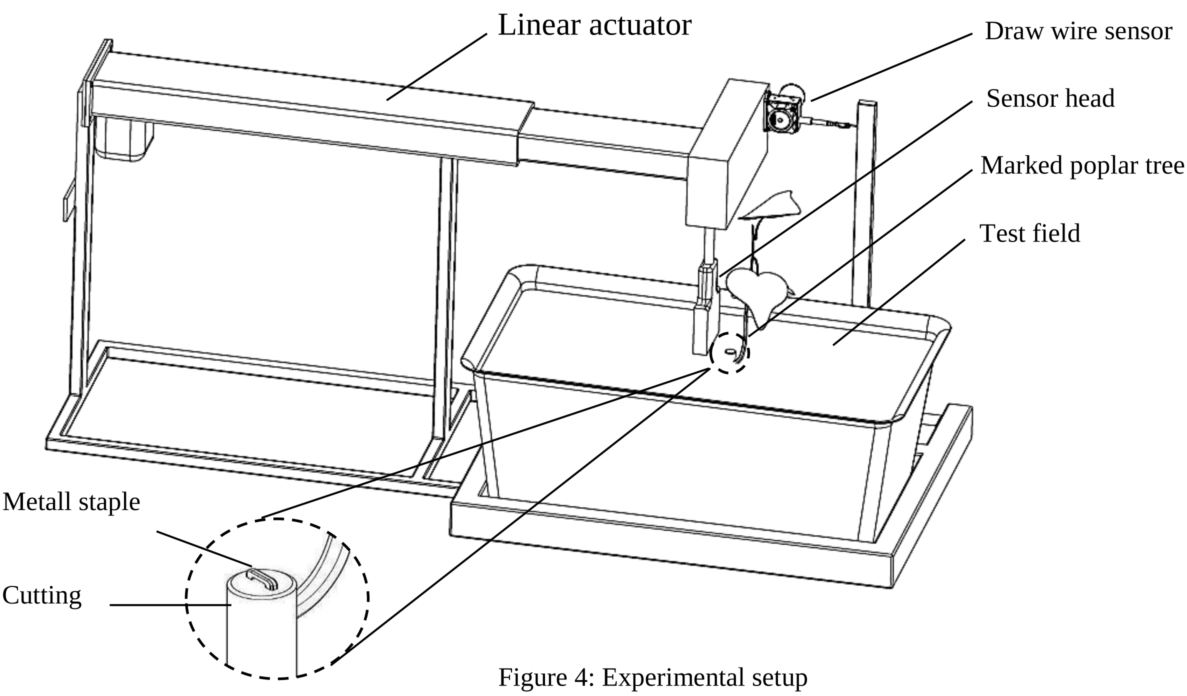

Figure 4: Experimental setup

The diagram displays the voltage of the sensor signal while the sensor head is approaching the marked cutting. The idle level of the signal is 5 V but sensor faults can induce short-term voltage drops. In a distance of 4 cm the metal mark on the cutting influenced the sensor signal and the voltage level alternates between 5 and 0.4 V.
The microcontroller decides for a tree in front of the sensor head if the signal fulfills the decision criteria. Three sets of criteria have been investigated.
The first is a simple threshold for the voltage level of 0.49 V. The results of a measurement series (100 detections) with a high weed density (60 plants per m^2) showed a mean value for the detection distance of 3.8 cm and a standard deviation of 0.41 cm. One detection range was out of a realistic distance (more than 7 cm).
The second criterion is a number of more than 3 consecutive samples under a threshold of 0.5 V. The results of this measurement series (100 detections and a high weed density) showed a mean value for the detection distance of 4.7 cm and a standard deviation of 0.27 cm. 28 detection distances were out of a realistic range (more than 7 cm). Because of his high number of false detections the second criterion is not usable for the tree recognition.
A rolling mean of the last 20 signal samples as a basic for the third decision criterion produced the best results. The comparison with a defined threshold value of 3 V prevented false recognitions of trees caused by sensor faults.
The detection ranges of the third decision criterion are shown in a histogram with classes of 0.25 cm (Figure 6). It displays the incidence of the detection ranges of one measurement series (100 detections). The weed density in the test field was about 60 plants per m^2

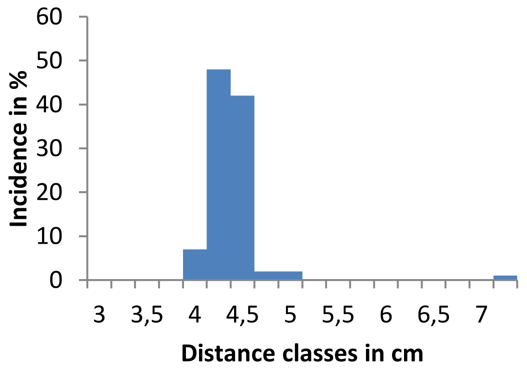

Figure 6: Incidence of detection ranges

With 48 % the most of the detection ranges are in the class around 4.25 cm. The average of all values is 4.35 cm. In this test, the number of tree detections outside a realistic distance between the coil and the marked cutting (more than 7 cm) is 1 of 100. The accuracy and the repeatability are very high (standard deviation of 0.18 cm).
It was possible to detect the marked cuttings between other plants in the test field with the investigated method. Most of the detection distances ranged from 4 to 5 cm.

6 OUTLOOK

Based on these results a machine concept for an autonomous robot must be developed in a future project.

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