Automated site-specific overseeding of grassland

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Abstract:

Vegetation gaps in pastures and meadows reduce yield and provide habitat for weeds. Overseeding is an economical way to regenerate grassland, but is usually only applied if gaps exceed 20-30%. With conventional sowing machines, the entire grassland is overseeded. About 70-80% of the seeds are wasted, because they fall on dense sward and do not germinate or are suppressed by the present plants. The costs of seed loss prevent farmers from overseeding at an early stage of grassland degradation. A sowing machine with site-specific sowing capability could reduce these costs. This would encourage farmers to sow at an earlier stage, potentially resulting in better swards with higher fodder quality.

We developed a sowing machine prototype with site-specific sowing capabilities. It detects gaps in grassland swards by means of image recognition. If a gap is detected, the on-board computer specifically opens a sowing valve of the pneumatic sowing machine and applies seeds at this specific place. Validation experiments confirmed that vegetation gaps are detected. The employed technique will allow to drastically decrease seed utilization and therefore costs. Thus, it has great potential to improve the management of pastures and meadows.

Keywords: overseeding, site-specific sowing, grassland, detection

Introduction

To ensure high quality feed, grassland must be kept in good condition. Due to weather conditions or excessive grazing however, gaps sometimes appear in the sward. This provides space for weeds such as rough meadow-grass, which has negative impacts on yield and fodder quality. As seed costs are high, timely resowing of the grassland gaps is often missed. Common practice is to overseed if 20% or more of the sward show gaps [2].

The overseeding procedure depends very much on weather conditions [3] and on competitive pressure of the existing sward [4]. Seeds can only germinate and close the gaps, if they are in direct contact with the soil and have enough space and light to grow. In case of many small gaps, a considerable amount of seeds are suppressed by the existing vegetation [5]. These seed losses can reach up to 90% [6]. The goal of the present project is to reduce these signficant seed losses by means of a site-specific seeder.

Material and method

The system which developed in this project consists of a camera placed in front of the tractor, a data processing unit on the tractor and an adapted pneumatic seeder. The seeder either applies seeds on the grassland or returns them back into the seed tank.

Abbildung 1: tractor with camera in front and seeder at the back

Image recognition system

An image recognition system was developed to identify the gaps in the sward. The industrial RGB-camera UI-1240ML-C-HQ (IDS Imaging Development Systems GmbH, Obersulm, Germany) with a resolution of 1.3 MPixels and optics with a focal length of 6mm (60 degrees aperture) was chosen. The distance between the camera and the seeder is individually adjustable. The mounting height of 1.40 m above ground covers a working width of 3.15 meters. To avoid dust and dirt and to receive enough processing time the camera was mounted in front of the tractor. We used the Tegra K1 (NVIDIA, Santa Clara, United States of America) as data processing unit. Beside the detection of the gaps in the sward, the driving speed has been determinded by image analysis (cross-coreletion of shifted images). The driving speed is used to calculate the right timeing for the opening of the seeding valves.

The gap detection in the grass sward is performed by image binarization. Hereby each pixel is either assigned to grass (white) or soil (black). In a next step the images of the working width are split in squares of 37x37 cm. These squares are in accordance with the working width of the eight single seeding valves. Within each square the percentage of grass is computed. If grass coverage is lower than 70%, the seeding valve will be opened and the sqare will be seeded. The developed algorithm is the property of Krummenacher AG, Dietwil.

Site-specific seeder

Site-specific overseeding requires a very short reaction time of the sowing machine. This issue was solved by circulating the seeds permanently through the seeding tubes. If a gap is detected, a Y-valve opens and the seeds are guided through another tube towards the soil. The airflow is strong enough to avoid seed blockage inside the hoses.

The electronic power driver of the valve actuator has been based on the DRV8828 from Texas Instruments (U3 in schematics). Each valve is driven by one power driver. The local management of the power drivers is done by the microcontroller (PIC16F1829). The valves are operated from the central controlling unit via an RS422 link. A PCB (Printed Circuit Board) has been manufactured to assemble all the elements. An aluminum housing provides protection from the harsh environment of agricultural vehicles.

Field and performance tests

Technical tests: The system has been tested on several fields. On each test field three test areas in the size of 3x20m were marked with barrier tape on the ground. To check the technical functionality twelve wooden plates with dimension of 15x15cm, 20x20cm and 25x25cm were laid on the soil from each test area. To check the functionality of the system checked visually, if the seeds hit the wooden plates and images of this area were recorded. The driving speed was 5km/h and 3 repetitions have been executed.

Pracital tests: Practical tests were carried out during two seasons on three different meadows. These were permanent grassland sites with the common mixture of grass (approx.. 50 %), 20 % clover, 10% herbs and 20% gaps. Before onset of the experiments, the grass on the meadows was cut to an average height of 8cm to simulate practice overseeding conditions. On each selected meadow, three different test areas of the dimenson of 3x5-20m were determined. Pictures were taken to check the detection accuracy later on. It was a cloudy day with diffuse sunlight. To determine the accuracy of the recognition algorithm, the binary images indicating grass and soil, generated by the image recognition system, were compared in the field with the real situation. The over- and underestimated gaps in the sward were marked on the binary images in red resp. in yellow. Finally, the number of pixels of the four groups have been counted: vegetation (white), soil (black), overestimated soil surface (red), underestimated soil surface (yellow).

Results

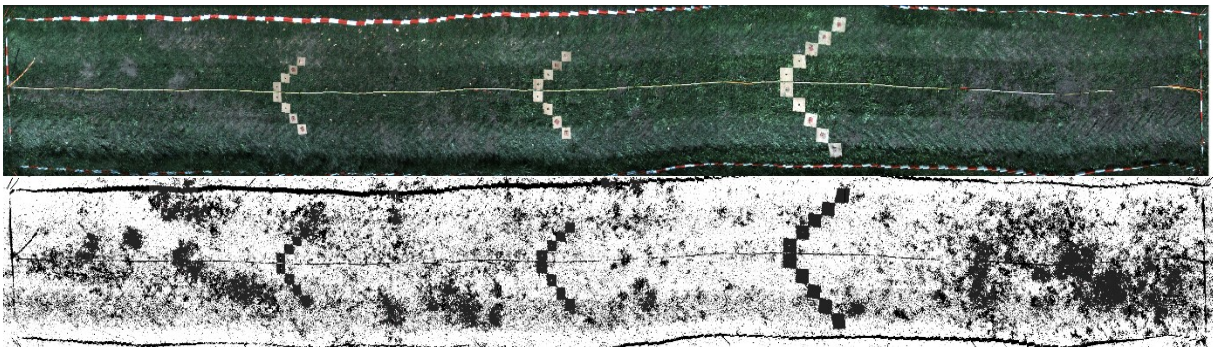

Figure 2: test field with wooden plates simulating gaps in meadow

Technical tests: Technical testing showed that the wooden plates were exactly detected regardless of their size (fig. 2). Also other gaps on the test field were well detected. The visual control showed that the timing of the valves worked well and that the seeds hit the plates precisely.

Field tests: The image recognition system showed a high recognition rate of “soil” and “vegetation”. Green vegetation was recognized 100 % correct. A surface covered with lying hay or brown stubbles of about 5 % (Table 1) has been recognized as “soil”. The attribution of bare soil surface to “soil” was correct too. The column yellow in table 1 indicates that no green vegetation has been interpreted as soil.

Table 1: Number of pixels of the four characterized groups of the three fields

test fields	nr. of test field	pigment content		fault	
		white vegetation [%]	black soil [%]	red overestimated [%]	yellow underestimated [%]
Langwis	1	54%	44%	4%	0%
	2	69%	29%	6%	0%
	3	90%	10%	3%	0%
	4	81%	18%	4%	0%
Haerenpuent	5	92%	7%	5%	0%
	6	81%	19%	2%	0%
	7	92%	8%	2%	0%
	8	90%	9%	1%	0%
Teststrecke	9	77%	21%	10%	0%
	10	79%	19%	9%	0%
	11	86%	13%	7%	0%
average		81%	18%	5%	

Discussion

Field tests: The technical and practical tests showed that gaps in grassland can be overseeded very precisely and site-specifically. The green covered surface was interpreted correctly, however brown stubbles, hay and other residues increased the recognized soil surface. However, brown stubbles might be dead plants, which indicates that the recognition is correct. The field situation compared to the generated binary image (vegetation-soil) showed that it is not always easy for a human observer to correctly interpret a particular situation.

The field tests were carried out under diffuse light conditions. We could see in other trials, that detection accuracy decreased under bright sunlight, as plant shadows might be interpreted as bare soil (results not shown). This aspect needs further development.

To realise a short reaction time, seeds are kept in permanent circulation. This circulation may alter the germination rate of the seeds, due to abrasive effects. Germination tests with seeds treated with 50 circulation cycles however did not show any effect of this treatment (results not shown).

Economical considerations: In Switzerland one kilogram of seed cost between 6,90 EUR and 18,70 EUR – depending on breed and mixture [7]. If the seed loss could be reduced by 70 %, compared to the common overseeding procedure, seed costs between 96,60 EUR/ha and 392,70 EUR/ha could be saved. With an annual machine utilization of 20 ha/a, between 1932 EUR and 7’854 EUR of seed costs could be saved. An annual saving of 1’932 EUR could amortize an investment of 15’560 EUR, (12 years amortization; reparation factor 0,25; interest rate 2%). This shows the range to which extend such an investment could be profitable.

Conclusion

The results show, that site-specific overseeding of gaps in grassland swards is possible. Different lighting conditions are still a considerable problem in detection accuracy. Here, further investigations have to be made to resolve a practicable System. By solving the technical challenges, the system could be capable to decrease the costs for overseeding and though to increase the yield and quality of grassland.

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