Machine vision detection and microwave-based elimination of *rumex obtusifolius L.* on grassland

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Abstract

Rumex obtusifolius L. (referred to below as rumex) is a common weed on grassland used for basic feed production. The aim of the project is to detect individual rumex plants with the aid of an image processing system. Image data are acquired and detection takes place offline initially. A detection accuracy of 87 to 97 % was obtained in five datasets with 941 images and 563 manually verified rumex plants. The proportion of objects wrongly classified as rumex to effective rumex was between 6 and 35 %.
A further module is under development with the aim of eliminating rumex plants using non-chemical methods compatible with organic farming and with a reduced labour input. The effects of microwaves on rumex plants are being studied in exploratory tests. The control success rate with a heating area of 37.0 cm^2 was approximately 80 % elimination of treated rumex plants.

Keywords: Machine vision, Detection, *Rumex obtusifolius L.*, Microwave, Grassland

Introduction

Three quarters of the utilised agricultural area in Switzerland is grassland. Over 10 % of the farms are run according to organic farming guidelines. In some grassland-dominated regions, the proportion of organic farms may even reach 50 %. In organic farming systems, the use of feed concentrate is limited, so that the basic ration must cover the greatest possible proportion of the ration for cattle. It should therefore be possible to eliminate competing broadleaved weeds such as *rumex obtusifolius L.* on meadows using non-chemical methods compatible with organic farming and with a reduced labour input compared to manual removal. The aim of the present project is the automatic detection of rumex plants by machine vision and their subsequent elimination using microwaves.
Microwave technology has been under discussion for some time as a means of weed control. The main advantage of microwave technology over using herbicides is that it avoids leaving toxic residues in the soil. Interest has consistently focussed on superficial microwave radiation using waveguides and its effects on seed germination (Lambert *et al.*, 1950; Davis *et al.*, 1971, 1973; Diprose *et al.*, 1984) or post-emergence killing of whole plants (Wayland *et al.*, 1975; Kunisch *et al.*, 1992). Vela-Múzquiz (1983) also describes microwave technology as killing underground rhizomes.

Materials and methods

Detection

The image acquisition system comprises an external light covering, an artificial light source, an industrial digital colour camera with a resolution of 780×582 pixels, a frame grabber PCI card and a standard desktop computer. At the moment, detection is carried out offline with the “Qualireader” software (QualiVision AG, Oberrieden CH).

The algorithm developed by Rubio *et al.* (2002) is used to delimit homogeneous regions in the digital images. The detection algorithm searches for image regions in the grey-scale channel with high homogeneity in contrast. To this effect, the images are split into cells (e.g. 50×40 = 2000 cells). Then, for each individual pixel of a cell, the system determines the local binary patterns (LBP) as a parameter for the similarity of the grey value of the pixels. To calculate the LBP for an individual pixel, the central pixel is surrounded by a 3×3 pixel mask (Fig. 1). A mask is then formed with a 1 for each pixel with a grey-scale value greater than or equal to the central pixel (“thresholded”). The weighting factors are then multiplied by the mask (“weights”) and added to obtain the LBP for the central pixel.

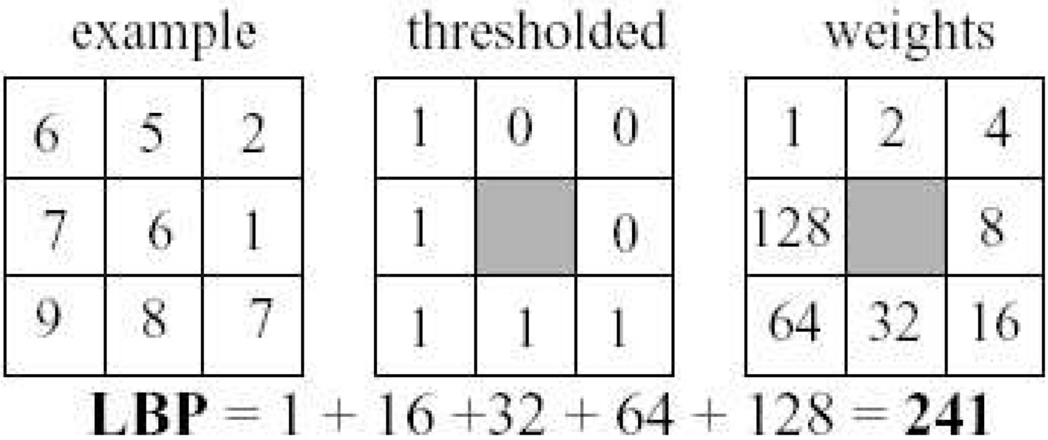

Figure 1. Example of calculation of the local binary pattern (LBP). The LBP is calculated for the central pixel in a 3x3 matrix.

To obtain the contrast value, the mean is taken of all the neighbours with the mask value “1” and the mean of all the neighbours with mask value “0” is deducted. In the case of the sample pixel in Fig. 1, the contrast value is thus as follows:

$$C = (6+7+9+8+7) / 5 – (5+2+1) / 3 = 4.733$$

The LBP and C histograms of the cells are then compared and combined into regions using a threshold. These regions are subsequently classified by size and colour criteria as a “rumex plant” or “background”. To improve the accuracy and flexibility of the classifier, regions can be manually assigned to the target object or the background (with the option of other classes) in a teach mode, thus establishing a prototype set.

Weed control
In an exploratory test, individual plants were heated for different periods using a standard 1.2 kW microwave oven (Gigatherm AG, Grub CH) for edificial drying. The killing rate and regrowth were subsequently observed over several weeks.

Results

Detection
A detection accuracy of 87 to 97 % was obtained in 5 datasets with 941 images and 563 manually verified rumex plants. The proportion of objects wrongly classified as rumex to effective rumex was between 6 and 35 %. The detection accuracy depends very much on the surrounding vegetation. In meadows with a high proportion of weeds, detection accuracy declines and the erroneous detection rate rises. Figure 2 shows an original image and the homogeneous regions detected by the algorithm. The homogeneous regions are then processed by the classifier and divided into "rumex plant" and "background".

Figure 2. Screenshot from the Qualireader detection software. On the left, the original image; on the right, the homogeneous image regions detected that will then be classed as "rumex plant" or "background" by the classifier.

Weed control
No successful weed control was measurable with a 1200.0 cm^2 (30.0×40.0 cm) heating area (Tab. 1). With a reduced heating area of 37.0 cm^2 (4.3×8.6 cm) and a minimum heating period of 60 seconds, 12 out of 15 plants (80 %) were eliminated. All the plants not killed off had rhizomes extending beyond the area heated. Re-sprouting occurred from rootstocks adjacent to the heated area.

Table 1. Experimental system for microwave killing of rumex plants. The two heating areas of different sizes were used for different heating periods. The results (x/y) show the number of dead rumex plants (x) as against the number of treated rumex plants (y).

	Heating period (sec)							
	60	120	180	240	300	480	720	1200
Heating area: 1200.0 cm^2	0/0	0/0	0/0	0/1	0/1	0/1	0/1	0/1
Heating area: 37.0 cm^2	2/2	3/4	4/4	3/4	0/1	0/0	0/0	0/0

Conclusion

The aim of further work will be to verify and improve the detection algorithm in different meadow types. In meadows with a high proportion of weeds and clover, in particular, the detection rate needs to be improved and the erroneous detection rate reduced to permit practical application.

Further development towards a prototype will be based on the promising exploratory trials with microwave technology for killing individual rumex plants. In future research, the microwaves will no longer be produced by a standard oven with the aid of a waveguide at the target area, but will instead be emitted radially by a 10 cm long probe inserted into the rumex plant, with the aim of improving the efficiency of the microwave power used. To further shorten the treatment time, the microwave power will be boosted from 1.2 kW to 4.0 kW for the forthcoming prototypes. These prototypes are intended to demonstrate the effectiveness of microwaves in controlling rumex plants. Another aspect to be investigated is how a heating period of around 10 to 15 seconds can be achieved with a high degree of control success.

Ultimately, both modules – detection and control based on microwave technology – will be combined as one weed control unit.

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