Determination of Weeds in Agrophytocenosis in Site-Specific Agriculture

Janis Repsons
Latvia University of Agriculture, Department of Soil Management,
e-mail: repsons@dzelme.net

Abstract
A study has been conducted in cooperation with the University of Bonn. The weed determination and weed control system based on digital photo analysis, GPS, and GIS, usable for various farms under the conditions of Latvia, is being worked out. Significant reduction in pesticide usage and environmental preservation have been reached via site-specific, selective herbicide application. Digital image analysis is used to identify weed seedlings of the most typical vegetation in cereal sowings in Latvia. The weed species identification is needed to select postemergence herbicides and to assess weed seedlings distribution in the fields. The reduction of herbicide treatments can be realized by selective herbicide application, when weed control is limited to field areas where specific weeds are present.

Images were captured in near-to-infrared light with a digital camera. The images were processed with the computer — binarized, weeds contours were extracted, and shapes — analyzed (including parameters of the external contour such as roundness, compactness, area, and 40 Fourier descriptors). The investigations were carried out in cereal sowings in Latvia.

Key words: site-specific agriculture, automated weed recognition.

Introduction
A study has been conducted to prevent nature pollution caused by unnecessary herbicide usage, to obtain economical gain for agriculture via developing and improving an automated weed recognition system designed at the Friedrich-Wilhelm University of Bonn, and to use it for weed detection and patch spraying under the conditions of Latvia.

In Latvia, weed patch spraying is actual in most of the fields, which are five hectares large or more. Of course, it depends — there might be some large fields, where uniform spraying can be applied without significant herbicide wasting (compared to site-specific application).

Most of the fields have non-homogenous weed density with weeds located in several patches where, as in other field areas, herbicides (for example, specific, expensive herbicides against CIRAR, AVEFA) might not be used at all. This threshold level of weeds depends on the possible yield loss and economical calculation as “not worth to spend, but worth to save”.

This paper is mainly a theoretical literature review of methodology and techniques for creating and improving an automated weed detection system for use under the conditions of Latvia.

Materials and Methods
In vegetation hall conditions at the University of Bonn, Germany, germinating plant samples (60 species) were grown. Over 40 weed species and six crops (barley, wheat, oat, sugar beet, rape, maize) were successfully growing, and pictures were successfully taken.

The purpose of the investigation: for creating a plant-form parameters’ knowledgebase, collect digital pictures of weeds, which later will be used for automated weed detection in field conditions. The pictures of weeds were taken once every two days until the weeds’ six leaves stage.

For image recording, the nIR camera-framegrabber-computer system was used (a Kodak grayscale camera with resolution 1024*1024 pixels, sensitive in nIR). Very high image precision — approximately 5 pixel/mm — was used. For image processing, hardware and software equipment of the Institute of Plant Cultivation of the University of Bonn was used.

Results and Discussion
Possible economical and environmental gain from precise herbicide application in patch spraying
A lot of research have been done showing clearly that not all parts of fields require the same amounts of herbicides. For example, Von Lettner et al. summarize1 that economic threshold is often reached only on 50% of arable land. The possible savings in herbicide usage vary between 50 and 70%. Significant savings in precise herbicide use are possible by implementing adequate thresholds.

In areas where weed density is below the weed control threshold, herbicides are not used. In a 4-year experiment with a GPS-equipped sprayer at the Dikhopshof research station of the University of Bonn in Germany, average calculated savings of herbicide usage made 54% (Timmermann, Gerhards, Kuehbauch, 2004). Mr. Gerhards points out that savings are strongly dependent on crop and year. For grass weed herbicides, the savings were 90% in winter cereals, 78% — in maize, and 36% — in sugar beet; for herbicides against broadleaf weeds, 60% savings were in winter cereals, 11% — in maize, and 41% — in sugar beet fields. The economical gain from reduction in herbicide use varied between the crops, it was dependent on the amount and price of herbicides used. In maize, savings made 42 €/ha, in winter wheat — 32 €/ha, and in sugar beet — 20 €/ha (Gerhard, Christensen, 2003). In barley sowings (Dicke, 2004)

with site-specific weed control, 54% of herbicides against *Galium aparine* (GALAP) and *Cirsium arvense* (CIRAR), 96% of herbicides against grass weeds, and 94% of herbicides against broadleaved weed species were reduced.

**Techniques of image acquisition and processing**

To provide a precise, environment-saving herbicide application system, a weeds patch spraying and automated weed detection-decision-making system with good computer vision capabilities is necessary. To detect weeds automatically, good quality images are used, as well as powerful computer equipment, are needed because image processing “costs” a lot of CPU usage.

Several types of cameras are used worldwide, and different approaches exist — either tractor-mounted and close-to-soil surface or airborne mounted (remote sensing). As J.V. Stafford says (Stafford, 1997), it is possible to see weed patches via airborne remote sensing, but data must be complemented by others such as assisted manual surveying to create application maps for patch spraying.

**Recognition principles**

Some researchers (e.g. R.H. Biller et al., 1997) do not use video-camera systems but optoelectronic sensors. They detect and analyze light reflected by soil and plants to distinguish green objects — plants (Biller et al., 1997). Such systems might be very useful to spray and save glyphosate herbicides. Unfortunately, this system is not capable of distinguishing and detecting crop plants from weeds. D. EhIert (2004), for detecting weeds, worked in empty space between crop rows. There detection principle was to count every small, green plant as a weed, but big objects — as crop plants. In early 1985, Woebbecke and Meyer (1995b) established an interesting fact that the Fast Hadamard and Fast Fourier frequency transform methods can be used to classify inter-row video images, and the Fast Hadamard transform was as effective as the Fast Fourier transformation, but over 20 times faster.

Kühbauch, Gerhard, Sökefeld et al. have worked for some ten years at the University of Bonn to create a complete system, which now is capable not only of distinguishing crop plants from weeds, but also of detecting several weed species. For the weed species detection, plant shape parameters are used (length, width of leaves, and form factors). M. Sökefeld (Sökefeld, 1997) describes in detail mathematics used to detect weeds and crop species in his PhD paper. This system for plants two-dimensional description uses not only the plant’s size, area and span width, but also the Fast Fourier transformation description.

**Image acquisition**

There are two main approaches to capture images and extract plant shape contours for comparison with samples in the knowledgebase: first is to use RGB (red-green-blue) human visible light images, second is near-to-infrared (further in the text abbreviation nIR is used). Images in nIR are taken in a 700–1000 nm wavelength. This wavelength is very appropriate due to plants’ higher reflectance of light than that of soil’s. The final result is quite a good contrast image with brighter plants over darker soil. Woebbecke et al. (1995a) valued the near-infrared video system as superior to the color system for detecting weeds in inter-rows. R. Gerhard, W. Kühbauch et al. use nIR and bispectral (nIR+green) cameras in field conditions. Bispectral cameras with image preprocessing in chip level give excellent contrast images where plant contours are perfectly visible, but non-plant objects (stones) are not visible (Sökefeld, 20042). There might be used RGB cameras, too, similarly as Petry (1998) and Peretz et al. (2000) do it. In this case, a specific plants image extraction program with specific plants color space coordinates calculation is needed (Woebbecke et al., 1995a).

Weed patch spraying can be done either online or offline. Offline processing, with spraying later, has a benefit — it allows calculating precisely the amount of each herbicide to be used. Online processing should work "as go", but Sökefeld (2004) says that requirement for a direct injection system for site-specific herbicide application is based on weed detection. The type of weed detection and the resulting detection time is the crucial factor for the whole weed detection system (on-line or off-line) and for its performance, especially for the acceptable delay time of the direct injection system.

**Conclusions**

From literature studies it can be concluded that the Precision Farming Weed Control technology system can give significant savings in herbicide use by automatic weed detection and precise patch spraying application.

Even nowadays image capturing for such needs has not been solved via remote sensing due to lack of the required very high image precision (more than 1 pixel/mm). For the best quality, very detailed pictures are needed; therefore use of close-to-surface, tractor-mounted cameras are preferable.

Generally, for weed recognition, there might be used all types of cameras — RGB and nIR, but the best results are possible by using some combination of IR and visible light spectrum. To find the best low-cost solution, it is worth to study possibilities of using ordinary industrial RGB cameras.

For weed detection, a knowledgebase of weeds form span-width, Fast Fourier transformation and other parameters can be successfully used.

Computer-based image analysis and weed detection consume a lot of CPU time requiring powerful computers. As more images per field and per every second we take, as more computing resources are needed.

Now, in the development stage of the project, even significant savings of herbicides might justify only some costs of developing the automatic weed detection and application of the Precision Farming Weed Control technology system.

Optimistically, the system might be started testing in practical farming in Latvia in 2006 at the very earliest.

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References


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