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VISION-BASED WEED IDENTIFICATION WITH FARM ROBOTS

KISHORE C. SWAIN[1], MICHAEL NØRREMARK[1], DIONYSIS BOCHTIS[1], CLAUS GRØN SØRENSEN[1], OLE GREEN[1]

[1] K. C . S wain, University o f Aarhus, Faculty o f Agricultural S ciences, De partment o f A gricultural Engineering, Blichers Allé 20, P.O. box 50, 8830 Tjele, Denmark, Kishore.ChandraSwain[a]agrsci.dk
[1] M. Nørremark, Michael.Norremark[a]agrsci.dk
[1] D. Bochtis, Dionysis.Bochtis[a]agrsci.dk
[1]Claus Grøn Sørensen, claus.soerensen[a]agrsci.dk
[1] O. Green, Ole.Green[a]agrsci.dk

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ABSTRACT Robots i n a griculture of fer new oppor tunities for re al t ime w eed identification and quick removal operations. Weed identification and control remains one of the most challenging task in agriculture, particularly in organic agriculture practices. Considering e nvironmental impacts a nd f ood qua lity, t he e xcess us e of chemicals i n agriculture for controlling weeds and diseases is decreasing. The cost of herbercides and their field applications must be optimized. As an alternative, a smart weed identification technique followed by the mechanical and thermal weed control can fulfill the organic farmers' expectations. The smart identification technique works on the concept of 'shape matching' a nd ' active s hape modeling' of pl ant a nd w eed l eafs. T he a utomated w eed detection a nd c ontrol s ystem c onsists of t hree m ajor t ools. S uch a s: i) e Xcite multispectral camera, ii) LTI image processing library and iii) Hortibot robotic vehicle. The co mponents a re combined i n L inux i nterface en vironment i n the eX cite c amera associate P C. T he l aboratory ex periments f or act ive shape m atching h ave sh own interesting results w hich w ill be f urther enhanced t o develop the a utomated w eed detection system. The Hortibot robot will be mounted with the camera unit in the front-end and the mechanical weed remover in the rear-end. The system will be upgraded for intense commercial applications in maize and other row crops.

Keywords: Weed identification, shape matching, agricultural robot, image processing

Introduction

Controlling weeds an d pests remains a ch allenge i n agricultural crops. T he w eeds n ot only r educe t he c rop y ield but a lso r equired l ot of i nvestment i n t erms of a pplying chemicals an d mechanical t ools t o m onitor t hem. I n p recision ag riculture, si te sp ecific management z one c oncept ha s be en us ed to a pply c orrect amount of pesticide a t t he correct place of requirement Sudbrink et al., 2001;Tredaway-Ducar et al., 2003).

Guidance and weed detection systems have been developed mainly to make more effective use of pesticides, either for band spraying along a crop row or detecting individual weed or crop plants for treatment (Marchant et al., 1997; Tillett et al., 1998). In order to deal with the variations in crop development and site-specific variations in a field, a sensor-based spray technology was developed; SensiSpray. The system consists of sensors to detect crop variation and a spray system to automatically change spray volume. Electronics and software were developed to use the output signal of the sensor to adapt spray volume (van de Zande, 2009).

Computer vision technologies have reached commercialisation in agri- and horticultural fields mainly to identify and locate crop rows (AgroCom, Garford) but recently also individual transplanted crop plants (Garford, THTechnologies Ltd). The typical computer vision guidance system identifies the location and centre of seed line, ridge or tramline, calculates the offset between the current position and the desired position, and completes laterally control by moving an electromechanical/hydraulic steering system (Tillett et al., 2008, Søgaard and Olsen, 2003, Bakker et al., 2008). However, various methods and systems for automatic identification and mapping of weed species by machine vision have been proposed. Manh et al. (2001) proposed to segment individual weed leafs based on the use of parametric deformable templates. However, they only considered one weed species. Sukefeld et al. (1994) and Sukefeld et al. (2000) described and identified weed plants based on Fourier descriptors and shape parameters for more than 20 weed species. The average rate of correct identification was 69.5% for weeds with only cotyledons and 75.4% for weeds with one or two pairs of leaf.

Agriculture robots are smart autonomous vehicles developed based on agronomic, economic and environmental needs and is capable of doing field main operations; crop establishment, plant care and selective harvesting (Blackmore et al., 2004). Robots have the advantage of being small, light weight and autonomous, can collect data in close proximity to the crop and soil. They also bring several advantages, including safety, greater autonomy and efficiency, and lower cost. Furthermore, agricultural robots can benefit of the research provided recently on the mission level for automated field operations (Sørensen et al., 2004; Bochtis and Vougioukas, 2008; Oksanen and Visala, 2007; Bochtis and Sørensen, 2009, Bochtis et al., 2009). The first generation of agricultural robots was used to pick and harvest agricultural crops, equipped various sensors (cameras to detect weeds, and larger scale sensors to detect crop stresses and disease etc.) for crop status monitoring and GPS units for location information.

The objective of the research is to discuss about detecting the crop leafs from the weed leafs using shape matching technique and facilitates the system for agricultural robots using computer vision. The weed recognition approach presented in this paper is primarily intended identify weed using active shape modeling technique on-the-go spraying operation using Hortibot robot. To optimize the usage of herbicides, it is important to start spraying as soon as possible after the weed seedlings have emerged. Therefore, the study only focuses on weed seedlings, with up to two true leafs.

Materials and Methods

Camera and dot-sprayer

The main components of the dot sprayer system was a digital colour camera equipped with an embedded computer (eXcite exA640-120c, Basler Vision Tech., Germany) and a spraying unit (Fig. 1). The spraying unit consisted of 16 small solenoid valves (Willett 800, Videojet Tech. Inc., USA), controlled by a 16 MHz AVR microcontroller (Atmel Corp., CA, USA). The microcontroller received data packets for which valves to open from the camera serial port. The eXcite camera has inbuilt Linux operating system, used to carry out the image processing operation.

Basler's eXcite system merges the superior digital camera technology and a high-performance (1.0GHz Linux) PC in a small housing. The eXcite offers a single component capable of both capturing and processing images based on the application software. Using the eXcite's variety of integrated communications interfaces, including eight digital I/O ports, super-fast Gigabit Ethernet, and high speed USB 2.0, calculated results can be fed directly back into a production process without the need for additional hardware components. With higher demand for computer vision based solutions, the cost of the eXcite camera unit also reduced year-by-year with additional features and applications.

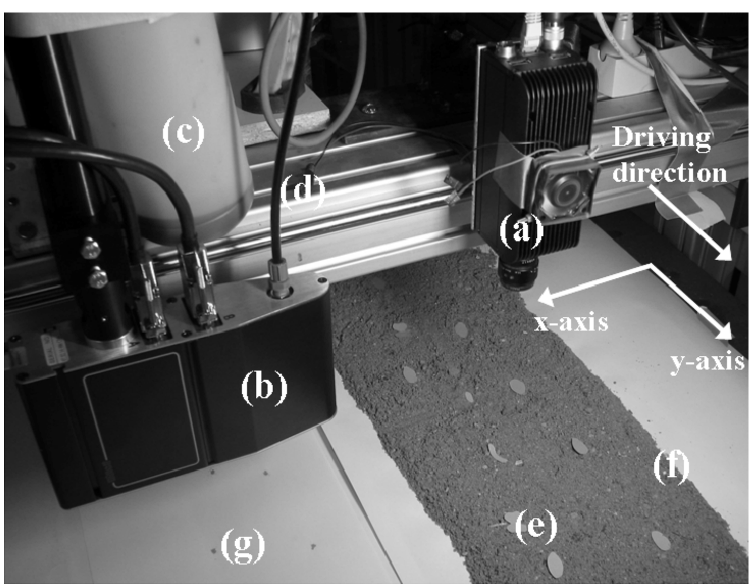


Figure 1. The camera and spray unit at the test rig. (a) Basler eXcite 'smart camera', (b) spray unit, (c) plastic container with water and tracer, (d) plastic hose, (e) simulated plant seedlings, (f) band of soil, (g) spray deposit on paper sheet (Swain et al., 2009).

LTI Library

The LTI-Lib is an object oriented library with algorithms and data structures frequently used in image processing and computer vision. It has been developed at the Chair of Technical Computer Science (Lehrstuhl fuer Technische Informatik) LTI at the Aachen University of Technology, as part of many research projects in computer vision dealing with robotics, object recognition and sing language and gesture recognition. The main goal of the LTI-Lib is to provide an object oriented library in C++, which simplifies the code sharing and maintenance, but still providing fast algorithms that can be used in real applications.

It has been developed using GCC under Linux, and Visual C++ under Windows NT. Many classes encapsulate Windows/Linux functionality in order to simplify dealing with system or hardware specific code (for example classes for multi-threading and synchronization, time measurement and serial port access).

LTI-Lib being a complete package for image processing has many tools and algorithms (such as: ANN, I O, centriod measurement, image comparison, filtering, image conversion, etc.) to support the 'shape matching' operation. Additionally, the classic edge detection, 2D and 3D draw distribution, HSI, HLS YUV and RGB processing will further support the image processing operation for intended weed detection application. Wide variety of image processing tool working with GTK interfaces in Linux working environment will be compatible with eXcite digital camera unit. The programs with least space requirement will also be an advantage for real time image processing. Though, the library program works at faster pace, the time requirement as well as the accuracy of the shape matching application has to be testing in field applications. The LTI-Lib algorithm can be modified to work for most commonly available image formats.

Hortibot robot

The HortiBot is an autonomous platform prepared for further research and development in agricultural application. The HortiBot hardware and software structure is therefore ready for addition of information systems capable of performing monitoring tasks, with special focus on pests monitoring and dependent on information from 'Farm Management' (the job to be done, geographical maps), from the general Environment (GPS coordinates, time) and from the Field (images of the local conditions).The Hortibot will mount the camera unit in the front-end and the mechanical weed remover or a sprayer in the rear-end.

Figure 2. Hortibot field robot

Software Development

The required algorithm is developed in Linux operating system using LTI Library image processing platform. The single leaf image processing technique consists of four stages. i) Image acquisition and pre-processing, ii) Edge detection, iii) Comparison of two images, iv) Reliability assessment.

i) Image acquisition and pre-processing

Images at 1-2 leaf stage were acquired using the eXcite camera unit. The images are generally stored in *.png* format. The images are masked to a single leaf, either a weed or a plant leaf using *Photoshop* software application. The 1-2 leaf images were supplied to the LTI-Lib for further processing. Around 40 images per min can be taken using eXcite camera.

ii) Edge detection

Edge of the leaf and plant is major basis of identification in shape and active shape modeling technique. The images were converted to gray scale image then to binary images. Sobel type edge detection technique was developed and used to detect the edge of individual leaf. The edge will represent the shape of the leaf. The leaf shape varies with the growth of plant. At 1-2 leaf stage, a no. of leaf sample edges would be collected and stored in a library.

iii) Comparison of two images

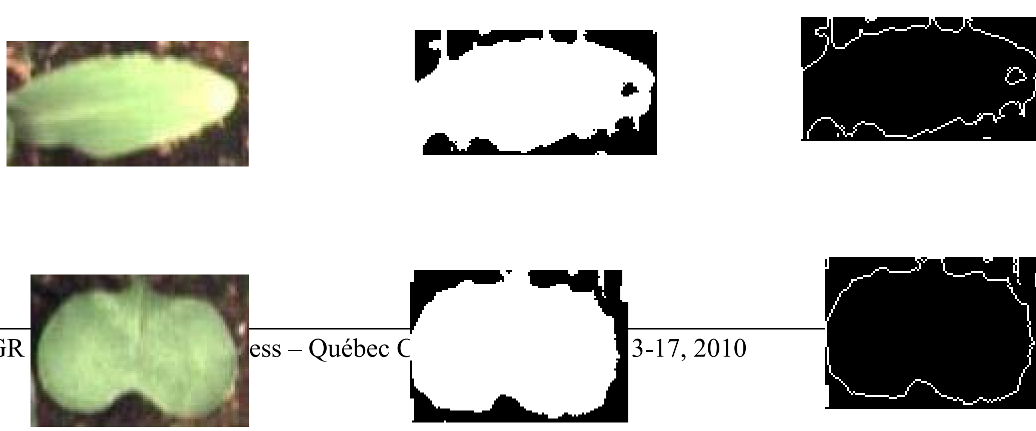
Point distribution model was developed for the shape of each leaf. The point distribution model of two images are supplied into the active shape modeling program as set of co-ordinates (x & y coordinates of each edge points). The edge of the leaf is scale down to hundred points as to that of library image. The no. of points of both the images is to be equal, in numbers, for this type of comparison. The point distribution model was used the following image comparison technique.

i) Center of gravity estimation
ii) Point to point distance estimation
iii) Scaling and orientation estimation.

The center of gravity of the image leaf were identified and used to place the sample library leaf shape preceded to the comparison. It will tremendously reduce the time of image matching. Point-to-point distance estimation is the basis of image matching. It is estimated for all the points. If it is very high, then scaling and image orientation features were estimated. According to the value of scaling and orientation of the current leaf image, the suitable library image will be selected for successive iteration. The distance will be again calculated and decision is made whether the shape is a maize leaf or that of a weed leaf. The system of normal to edge technique will also be tried to estimate the suitability of the technique. The best suitable technique is the one, which give higher correct identification of plant leaf at faster rate.

Results and Discussion

Image pre-processing



(a) (b) (c)

Figure 3: Leaf ddge detection, a maize leaf (above) and weed leaf (below); a) RGB image;

b) Binary image; c) Leaf shape image

The binary image was developed using an excess green index. It is estimated as follows

$$\%GI = (Green \times 3) / (Blue + Red + Green) \quad (1)$$

Where,

GI: Green Index

Blue, Green & Red: Pixel value for individual spectral band

The GI index will help in separating the green leafs (plant & weed) from non-green back ground and colored weed leafs. The edge was detected using a single 3x3 matrix image manipulation. The point distribution model will run for the shapes with more points and the small shapes will be discarded. The library of images will be created with a no. of images. It will be used to reduce the no. of iteration in terms of minimum point-to-point distance.

Shape identification

The no. of points of the sample shape and leaf shape were kept same to enable point-to-point comparison. The image resolution will be not an issue, which can be abated with translation of image. The time required, per iteration, is around 35 milliseconds. The technique found suitable for identifying single leaf images but not suitable for overlapped leaf images. To estimate the reliability and relevance of the technique, it will be carried out with on-the-go operation of system mounted on a Hortibot robot.

Conclusion

Active shape modeling is the most up-to-date technique for identifying plant leafs and separating them from weed leafs. The LTI Library, being distributed freely, has a no. of ready to use image processing software application, suitable for both Linux and Microsoft C/C++ programming environment. The system technique work well with single leaf images and more work required developing up-to-date library of sample images. The on-the-go operation of the system will enhance the suitability of the technique and will be commercialized later. Currently, the system is suitable for row crops, which can be upgraded for others agricultural crops.

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