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Image Segmentation in Agriculture Crop and Weed Detection Using Image Processing and Deep Learning Techniques

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***Abstract*: Artificial Intelligence, specifically deep learning, is a fast-growing research field today. One of its various applications is object recognition, making use of computer vision. The combination of these two technologies leads to the purpose of this thesis. In this project, a system for the identification of different crops and weeds has been developed as an alternative to the system present on the FarmBot company's robots. This is done by accessing the images through the FarmBot API, using computer vision for image processing, and artificial intelligence for the application of transfer learning to a RCNN that performs the plants identification autonomously. The results obtained show that the system works with an accuracy of 78.10% for the main crop and 53.12% and 44.76% for the two weeds considered. Moreover, the coordinates of the weeds are also given as results. The performance of the resulting system is compared both with similar projects found during research, and with the current version of the FarmBot weed detector. Form a technological perspective, this study presents an alternative to traditional weed detectors in agriculture and open the doors to more intelligent and advanced systems.**

***Keywords*: Artificial Intelligence, FarmBot, image processing, Matlab, weed detection.**

1. Introduction

One of the newest and most researched technologies nowadays is deep learning. Deep learning is a technique used to create intelligent systems as similar as possible to human brains. It has made a big impact in all types of domains such as video, audio and image processing (Wason, 2018; Sharma, 2019). On the other hand, agriculture is humanity's oldest and most essential activity for survival. The growth of population during the last years has led to a higher demand of agricultural products. To meet this demand without draining the environmental resources the agriculture uses, automation is being introduced into this field (Mehta, 2016).

The present project aims to merge both concepts by achieving autonomous weed recognition in agriculture; this goal will be reached by using new technologies such as Matlab, FarmBot and Python programming, image processing, deep learning and Artificial Neural Networks (ANNs). These concepts will be explained in more detail throughout this document. This paper is developed for a farming school in Töreboda, Sweden.

2. Problem Description

These last years the combination of automation and computer vision has been introduced into agriculture to reduce human workload. The FarmBot used in this project is one example of that combination. Its functions range from the automation of basic agricultural activities such as watering or seeding, to more advanced and complex tasks such as differencing between crops and weeds. This weed detection system is the focus of this project. It is programmed to take pictures of the crop and process them by a manually activated weed-detection software application from FarmBot where the processing is done based on the colours and location of the elements of the picture. This weed detector is the starting point of this thesis.

Why does the weed detector have to be improved? Even if this system seems to be fail proof, it is not. There are three main issues that can be considered: firstly, having to manually activate the weed detector application does not reduce the amount of human labour as much as intended. Secondly, basing the detection on colours is not accurate due to the possibility of a change of lighting or the similarity of colours between weed and plants, among other things. Finally, basing the existence of a weed on the location where the FarmBot has previously planted a seed, does not consider a situation where the FarmBot does not necessarily know where all the seeds are located. As a way to solve these issues, this thesis will implement a weed detector software based on deep learning which will be explained.

3. Aim and Objectives

The aim of this project is to implement a different type of weed detection system, one that makes use of an ANN to differentiate between crop and weed. In order to achieve this, some objectives need to be set:

1. Image capture using FarmBot
2. Image pre-processing with Matlab
3. ANN training using Matlab
4. ANN testing
5. Use the previous pictures to return weed coordinates

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6. Compare ANN performance between the one used by FarmBot and the one used in this project.

4. Computer Vision: Image Processing

Computer vision, also known as machine vision, is an area that comprises the acquisition, analysis and processing of images in a way as similar as possible to human vision, using at least an optical imager and a computer to obtain appropriate information (Lu & Lu, 2016; SAS, 2019).

A machine vision system consists of the following elements (Jähne & Haussecker, 2000; Nixon & Aguado, 2019):

- *Radiation source:* a proper illumination source is needed in order to observe the objects as precisely as possible.
- *Camera:* used to collect the radiation emitted or reflected by the object.
- Sensors: they transform the radiation caught into a suitable signal for its future processing.
- *Processing unit and memory system:* to extract features, measure properties and categorize them, as well as to collect and store information about the scene.
- *Actuators:* to react to the final result of the observation.

The imaging process (Figure 1) involves all the steps of the development of an image from a physical object. Therefore, the imaging system is composed of sensors that transform the radiation into electrical signals which are then sampled and digitalized. The objective of this process is to obtain a signal from a real-life object from which we can determine its properties and geometry through further processing, recognition and classification of objects.

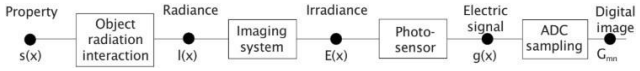


Fig. 1. Imaging process overview

A. *Image processing*

Image processing is a method to perform operations on an image in order to improve it for further analysis. In terms of computer vision, it is called 'digital image processing' due to the needed of a digital image to be processed by the computer (McAndrew, 2004).

The most common way image processing is performed into a computer vision system is the following:

1. Image acquisition: The camera and sensors take an image and digitalize it in order to process it.
2. Pre-processing: performing some basic processing tasks in order to have a suitable image to work with.
3. Processing: At this point, all the techniques required for the correct modification of the image are applied.
4. Representation and description: Extracting the most particular features of the objects from the already processed image, in order to differentiate these objects.
5. Recognition and interpretation: Assigning labels to those objects to completely define them.

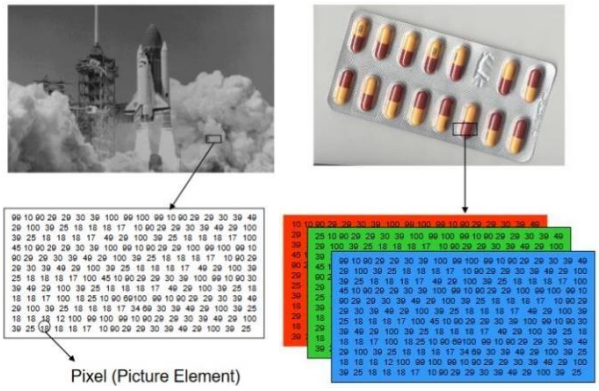


Fig. 2.

By processing each pixel and modifying its characteristics using image processing algorithms, the image can be improved or even changed completely. Mc Andrew (2004) divides those different algorithms depending on the tasks they do:

- Image segmentation: Divides an image into sub images in order to isolate or identify certain shapes.
- Image enhancement: Process an image to make it more suitable for an application.
- Image restoration: Reverse the damage done to an image due to a known cause.

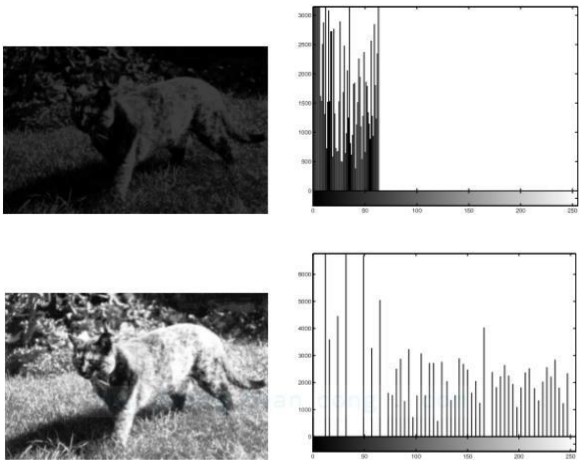


Fig. 3.

There are lots of different algorithms or techniques that can be used to process an image, hereafter the most used techniques are going to be explained (Reina Terol, 2019):

- Histogram: It shows how many times does a grey level appears in an image. Thanks to this, it is possible to know if the image is too light, too dark, etc.
- Filtering: Compares a pixel grey level to its neighbors' ones, normally to eliminate noise. There are lots of different types of noises and so are filters.
- Discontinuity detection: locating where discontinuities are because of the object's borders
- Edges: follows the edge of an object from a given point to locate the whole object.
- Connected components: follows the pixels that are next to each other on the object's border in order to detect the number of objects in the image.

- Cross correlation: making possible to compare two images to find its similarities.

a) Original

b) Gaussian

c) Salt & pepper

d) Filtered

Fig. 4.

B. *Artificial Intelligence: Deep Learning*

Artificial Intelligence is an area of computer science that tries to get computers to imitate human-like intelligent behaviour, such as reasoning, adapting and self-correcting. For a system to be called artificially intelligent, according to the Turing test, it would have to be able to communicate in a natural language, to have knowledge and to store it somewhere, to do reasoning based on the stored knowledge, and to be able to learn from its environment (Kok, et al., 2009).

Looking at these requirements, it can be said that one of the most important branches of AI is machine learning. A system which is in an evolving environment must possess the ability to learn and to adapt to such changes to be called intelligent, this is done by using ANNs as it will be explained bellow. In other words, an intelligent system should be able to automatically extract an algorithm for the execution of a task based on existing accurate data, in order not to replicate this data, but to correctly predict new cases. That is the aim of machine learning (Ertel, 2017; Alpaydin, 2016).

The way AI and machine learning try to imitate human behaviour is by using ANNs. An ANN is based on the brain function and its inner communication. It is made up of artificial neurons connected among themselves and can reinforce or inhibit the activation of the neighboring neurons. The ANNs consist on three basic layers of artificial neurons as shown in Figure 11: An input layer exposed to the input signals that transmits information to the following layer, the hidden layer. In this layer the important features are extracted from the information received, and then transported to the output layer (Neapolita & Jiang, 2018; Deng & Yu, 2014).

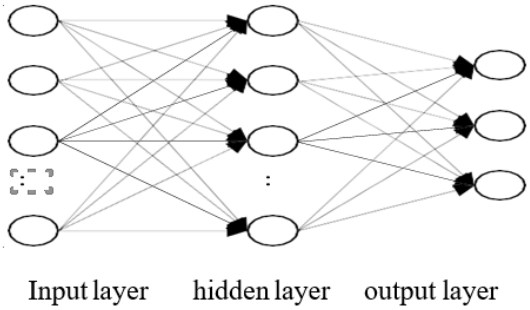


Fig. 5. Neural network architecture

C. *Weed Detection*

Agriculture has always been an essential activity for survival. Over the last century, and more specific, over the last 15 years, agriculture has started to mechanise and digitise; due to this evolution and automation, labour flow was almost totally standardised. Nowadays, after introducing robotics and artificial intelligence into agriculture there is no need of standardization, robots are working collaboratively with humans and learning from them how to realize the basic agriculture tasks such as weed detection, watering or seeding (Marinoudi, et al., 2019).

D. *Image Classification*

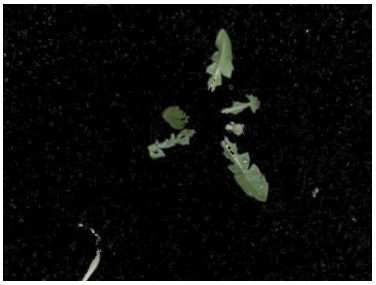
Image classification is done in Matlab. The aim of the Matlab code is to train a pre- created network in order to make it able to perform a classification between spinach and weeds. The full code explained in detail can be found in AppendixA, while the training and classification processes, the most important points, are discussed below.

Before starting to work with Matlab, there is one more step to perform. To work with the downloaded images, Matlab needs to know exactly what is inside of every picture. This has to be done manually by separating each downloaded picture in folders, named accordingly to the different categories the net is going to differentiate. Once this is done, Matlab accesses these folders and randomly divides the images in three groups: training, validation and testing, in order to work with them separately.

The training process is shown in figure. It consists in the

modification of AlexNet by changing its last two layers, and then trains it on the training set of images with some options that will determine how the network will learn. These steps are followed due to the selection of Transfer Learning as the network's learning method.

a) Original image



b) Image without background

Fig. 6.

E. Plant Detection

When it comes to finally detecting the weeds in a set of pictures, the initial steps of the program are similar to the ones done in training and test. Creating a data store of images, processing them and, if needed, obtaining the ground truth table to later compare the results with reality. In this part.

5. Results

Once the development of the weed detector is finished, the obtained results are: 54 images with the corresponding bounding boxes for each plant detected as well as its label, the precision of the weed detector for each category in this set of images, and a table with the coordinates of the weeds in the FarmBot bed. In addition to these results, a comparison of the performance of the resulting weed detector with the original FarmBot weed detector, as well as one of the neural networks.

6. Conclusion

In conclusion, the project developed in this thesis has successfully achieved the principal aim set. The principal aim of this thesis was the implementation of a system able to identify crops and weeds using ANNs with images captured by the FarmBot, which will later be compared with FarmBot built-in weed detector. The accuracy obtained is not of a 100%, but the network differentiates well enough the different type of plants it has been trained on. Therefore, the main aim of the thesis is considered as accomplished.

The objectives have been also achieved. The FarmBot has been used to takes the pictures and then those pictures have been correctly processed by Matlab, an ANN was trained and tested and then used to predict the crop and weeds at the pictures and also return the weed coordinates. Finally, a comparison with other methods was done. Therefore, all the objectives have succeeded.

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