Multi-class weed detection and classification system for tomato (*Solanum lycopersicul L.*) using neural networks.

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Angel TOLEDO[1], Juan LOPEZ-CORREA[1], Dionisio ANDUJAR[1]
[1] Centre for Automation and Robotics, CSIC-UPM, Arganda del Rey, 28500 Madrid, Spain

Introduction

Tomato (*Solanum lycopersicum L.*) is one of the most important agricultural crops in the world. Weed control is of great importance due to the cost associated with this crop as it can jeopardize its production. (Qasem et al., 2019). Although weeds are heterogeneously present in the field (Fernandez-Quintanilla et al., 2018). The conventional approach is to carry out a uniform herbicide application(Pérez-Ortiz et al., 2016). Therefore, site-specific management plays an important role in detecting and spatially positioning the distribution of weeds in fields with economic, environmental benefits and achieving better food quality (Tanget al., 2017). Object detection systems, using neural networks based on deep learning, are a potentially viable option given their extraordinary versatility.

The present work aims to develop an automatic weed detection and classification system for the following species: *Portulaca oleracea L., Cyperus rotundus L., Solanum nigrum L. Echinocloa cruzgalli L., Setaria italica L.*

Materials and methods

Image acquisition: Tomato (*Solanum lycopersicum L.*) plot located in the province of Badajoz (Spain) 1713 images taken from the zenith.

Image pre-processing: Image labelling using LabelImg (Tzutalin, 2015). Four weed species were classified and labeled (Figure 1) using the EPPO (*European and Mediterranean Plant Protection Organization*) code as follows:

Cyperus rotundus L. (CYP-CYPRO)
Echinochloa crus galli L. (ECHCG)
Setaria italica L. (SETIT)
Portulaca oleracea L. (POROL)
Solanum nigrum L. (SOLNI)
the tomato crop label was added
Solanum lycopersicum L. (LYPES)
added a category for unrecognized weeds
Not recognised by size (NCI)


Figure 1 Weed labeling

Dataset: 70% for the *training set*, and 30% for the *validation set*. The final dataset consisted of 1,713 images with 8,521 bounding boxes.

Neural Network Training: RetinaNet (figure 2), a one-step object detection and classification model (Lin *et al.*, 2017) using the implementation proposed by Gaiser et. al., (2019).

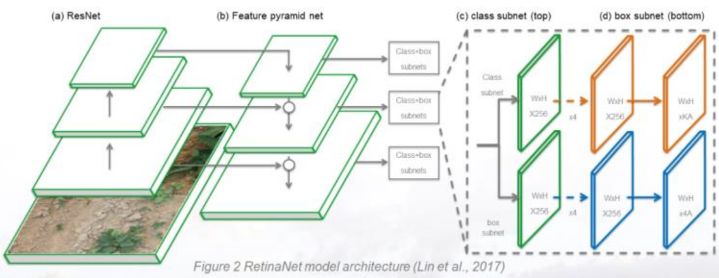
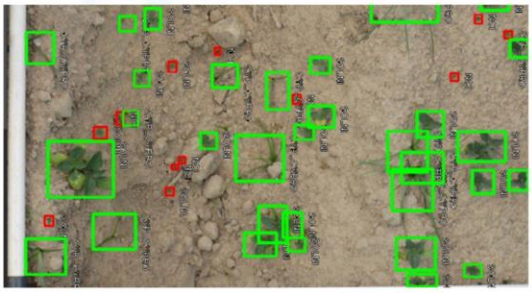


Figure 2 RetinaNet model architecture (Lin et al., 2017)

Quantification of prediction error: Using the *mean Average Precision* (MAP) metric (Padilla et al., 2020).

Results and discussion

- The dataset efficiently represented two of the major weed groups: *broad-leaved weeds* and *narrow-leaved weeds.*
- 100 training epochs were run and a mean pressure value (mAP: 0.92755) was obtained over the *validation set.* The mAP values per species are shown in Table 1.
- Discrimination between species with higher frequency and invasiveness in tomato crops in Spain, which are controlled with different types of herbicides.
- Discrimination between species within the same family.



Classes	Label	AP
Solanum nigrum L.	SOLNI	0,9209
Cyperus rotundus L.	CYPRO	0,9322
Echinochloa crus galli L.	ECHCG	0,9502
Setaria italica L.	SETIT	0,9044
Portulaca oleracea L.	POROL	0,9776
Solanum lycopersicum L.	LYPES	0,9842
Not recognised by size	NCI	0,8234
mAP		0,92755

Table 1: Distribution of PA values by class and mean value among all classes obtained from the predictions with the validation group.

Conclusions

The present work shows that automatic detection of the main weeds affecting tomato crop production in Spain is possible under real growing conditions. The precision values obtained are sufficiently high to perform effective selective controls. In addition, the obtained results of discrimination between species within the same family show a great potential for the identification of species with herbicide resistance. This weed species detection method based on *Object Detection Neural* Networks presents promising results not only for weed *vs.* crop selective controls, but also for weed species selective controls.

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Acknowledgments

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GESTIONANDO LA VARIABILIDAD PARA UNA PRODUCCIÓN SUSTENTABLE

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Angel Toledo[1], Juan LOPEZ-CORREA[2], Dionisio ANDUJAR[2]
[1]Chapingo Autonomous University, Texcoco de Mora, Mexico
[2]Centre for Automation and Robotics, CSIC-UPM, Arganda del Rey, 28500 Madrid, Spain
[*]d.andujar@csic.es

Industrial tomato (*Solanum lycopersicum L.*) is one of the most important agricultural crops worldwide. Weed control is of high importance due to the associated cost on this crop. Although weeds are heterogeneously present on the field creating weed patches, the conventional approach is to carry out an uniform herbicide application. Thus, site-specific management plays an important role by detecting and spatial positioning weed distribution within the fields. Object detection systems, using neural networks based on deep learning, are a potentially viable option given their extraordinary versatility. The present work aims to develop an automatic weed detection and classification system for the following species: *Portulaca oleracea L*., *Cyperus rotundus L*., *Solanum nigrum L*. *Echinocloa cruzgalli L.*, *Setaria italica L*. It employs one-stage object detection algorithm based on neural networks. For this purpose, a data set formed by RGB images, properly labeled in the European and Mediterranean Plant Protection Organization (EPPO) code, was developed and trained using Retina Net Object Detection Model. The performance evaluation with the mean Average Precision (mAP) metric, showed a result of correct classification higher than 90%, discriminating between tomato crops and the two groups broadleaf and narrowleaf weeds. In addition narrow leaf weeds were properly separated, such as, *Cyperaceae and Poaceae* families. This research is the basis of the development of intelligent tools for weed control in tomato fields looking for a more sustainable agriculture.