Title: Deep Learning: An e-monitoring tool for insect pests' detection (Invited)
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Abstract

Insect pests are animal species causing significant damages of global crop and fruit production every year. Against this event Integrated Pest Management (IPM) monitor and control practices are always applied. Pest monitoring aim to support the decision of counteracting a given level of infestation, as well as, to select the appropriate control mechanism. However, since most insects are similar, insect pests' detection on crops and fruits is more challenging than the general case of object detection. The manual (traditional) approach is based on placing, empirically, a number of traps in a cultivation area that are checked regularly by operators, in order to manually classify and discriminate insects in cultivation fields, a process which has been proven highly labor-intensive, time-consuming, and expensive. Various feature extraction methods have been applied so far for insect classification, including wing structures, colour morphometric measurements, histogram features, as well as local and global image features. In addition of the above feature extraction methods, well known classifiers, including support vector machines (SVM), artificial neural networks (ANN), k-nearest neighbors (KNN), and ensemble methods have also been applied. However, the above methods were only recently tested in real conditions, using images taken from traps already deployed in the cultivation field for pest monitoring. Further, the methods have also extended to be applied to specific insect pest catches, provided the use of pheromone traps to attract them.

Nowadays, the advent of Internet of Thinks (IoT) allows the real-time data acquisition based on electronic traps (e-traps) equipped with high resolution cameras and agro-climatic sensors for effectively monitoring the dynamics of the pest population and support the control decisions, respectively. In the semi-automatic case images of the captured flies are forwarded to experts for identification and classification analysis based on communication capabilities of the e-traps. The approach is improving the manual one in many aspects, however, there is still room for further improvements in terms of error detection made by human experts, and efficiency in terms of labor-intensive and time-consuming procedures. Various approaches for developing automatic detection and counting systems have already appeared so far, including machine and deep learning, image processing, spectroscopy, or optoacoustic techniques. Recently, deep learning algorithms have been developed to detect and count insect pests automatically and accurately that reducing to a minimum the human interventions. However, the detection problem of the various insect pests is still challenging due to their small size and similar shape, the light conditions the images were taken, and the limited data to train the learning model.

We focus on summarizing the progress made on image-based recognition approaches exploiting either machine learning, deep learning, or image processing techniques, and aiming to identify and count insect pests from images taken by a camera-equipped e-traps deployed in a cultivation field. We particularly discuss the capabilities of the proposed real-time e-monitoring system, as it measures pest population dynamics on a regular basis, using a large number of e-traps following various deployment patterns. We present examples of e-monitoring of pests, based on constructing a particular e-trap devise that captures insects on a sticky panel and transfer them to the cloud for processing. Limits and benefits resulting from several pilot studies are discussed with a perspective for the future improvements and developments.

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