Computer Vision and Image Processing for Detecting and Quantifying whiteflies: A Systematic Review

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RESUMO

A evolução da agricultura de precisão impulsionou o aumento da produção agrícola e proporcionou o surgimento de grandes desafios em termos de eficiência, segurança alimentar, sustentabilidade e impacto ambiental. Especificamente, o controle de pragas é de suma importância no que tange a saúde das plantações. Este artigo apresenta uma revisão sistemática da literatura, abordando técnicas e métodos de processamento digital de imagens em plantas para a detecção e classificação de pragas, em específico para a praga Mosca Branca. Nesta revisão foram considerados artigos publicados entre 2008 e 2018 indexados por cinco bases de dados científicas. A revisão identificou que as técnicas são bem exploradas, diversificadas e possuem alto desempenho em termos de acurácia. No entanto há uma dificuldade no que tange a detecção de moscas em estágio ninfal, e principalmente técnicas aplicadas a campo aberto e dispositivos portáteis, o que daria maior autonomia à agricultores e cientistas. Ideias futuras são discutidas no final do artigo com base nas dificuldades relatadas e trabalhos futuros propostos.
PALAVRAS-CHAVE: Visão computacional, classificação de imagens, agricultura de precisão, mosca-branca.

ABSTRACT

The evolution of precision agriculture increased agricultural production and provided major challenges in terms of efficiency, food safety, sustainability and environmental impact. Specifically, the pest management is extremely important healthy crop. This paper presents a systematic review of literature, addressing techniques and methods of digital image processing in plants for the detection and classification of pests, specifically for whitefly pest. In this review,

articles published between 2008 and 2018 indexed by five scientific databases were considered. The review identified that the techniques are well explored and have high performance in terms of accuracy. However, there is a problem with the detection of whiteflies in the nymphal stage, mainly techniques applied to the open field and portable devices, which would give greater autonomy to farmers and scientists. Future ideas are discussed at the end of the article based on the difficulties reported and future works were proposed.
KEYWORDS: Computer vision, image classification, precision agriculture, whiteflies.

INTRODUCTION

Precision agriculture can be considered as an exponent of general future development through the Internet of Things (IoT) and Big Data (WOLFERT et al., 2017). Modern technologies have given human society the ability to produce enough supplies to feed the demand of more than 7 billion people (MOHANTY; HUGHES; SALATHé, 2016). However, with the increase in production capacity, great challenges have arisen in terms of efficiency, food safety, sustainability and environmental impact. To address these challenges, the complex, multivariate and unpredictable agricultural ecosystems need to be better understood by monitoring, measuring and analyzing continuously various physical aspects and phenomena (KAMILARIS; PRENAFETA-BOLDú, 2018).

Image processing techniques (IPTs) can be used to enhance agricultural practices, by improving accuracy and consistency of processes while reducing farmers manual monitoring. Often, it offers flexibility and effectively substitutes the farmers visual decision making (SAXENA; ARMSTRONG, 2014). During the last several years, spectacular advances in the fields of artificial intelligence, computer vision, and deep learning have resulted in remarkable performance in image classification and vision tasks. (SCHWARTZMAN et al., 2016).

Linking this need to the emergence of new techniques, this paper aims to explore methods and tools of IPTs through a systematic review of the bibliography, with the objective of presenting the state of the art in the use of IPTs to identify the whitefly pest in images of plants.

WHITEFLY

The whitefly (*Bemisia tabaci*) is a major pest to agriculture. Adults are able to fly for long distances and to colonize staple crops, herbs and ornamentals, and to vector viruses belonging to several important taxonomic groups (BAR et al., 2019). If affects several cultures like pumpkin, zucchini, cotton, eggplant, broccoli, cauliflower, peas, beans, papaya, cassava, watermelon, melon, cucumber, pepper, cabbage, soybean and many others. The easiest way to control the pest infection is the use of pesticides. But the more use of pesticide are hazardous and it not only kill pest in plant , but also affect the health of human, animal and plant. To overcome this problem it is necessary to control the use of pesticide, pest detection is the most important process for an effective cultivation (JIGE; RATNAPARKHE, 19-2).

Figure 1: Leaf infested with whiteflies

Fonte (Embrapa, 2019)

Barbedo (2014) explains the most direct way of measuring whitefly infestation is to manually identify and count the insects inside a selected region. In general, this approach does not require sophisticated apparatus and, more importantly, relies on the remarkable human ability to resolve ambiguities and unclear situations, even under far from ideal conditions. On the other hand, human beings are susceptible to physiological and psychological phenomena that may be important sources of error: fatigue, visual illusions, boredom, among others. Also, humans are usually much slower than machines in performing simple tasks like counting.

Image processing has been proved to be effective tool for analysis in various fields and applications (VIBHUTE; , 2012). In this paper we explore some of these techniques to detecting and counting the whitefly pest.

MATERIAL AND METHODS

In this research, we performed a Systematic Review of the Literature (SRL), since it offers a organized and well-defined process. Mallett et al. (2012) defines SRL as a rigorous and transparency form of literature review. Three main stages were taken following the SRL guideline defined by Kitchenham e Charters (2007): (I) defining a review protocol; (II) conducting the review of the studies; and (III) reporting the review.

The review protocol definition include the definition of the research questions, keywords and search strategy, inclusion and exclusion criteria for the selection of studies and a checklist for study quality assessment. These elements is detailed next. To support this process and provide a collaborative way between the authors a software platform were used: Parsifal (https://parsif.al/).

Research questions

The main objective of this SRL was to answer the following question: “What is the state of the art in the application of digital image processing techniques for acquisition, detection and counting of Whitefly pest in images?”.

Some more specific questions that unfolded the previous one were formulated: (RQ.1) What are the existing methods for acquisition and preprocessing images for Whitefly pest? (RQ.2) What are the techniques used for detection and classification of pests in plants, specifically for the Whitefly pest? (RQ.3) What are the results obtained so far for detection and classification for the white fly pest? (RQ.4) What measures are used to evaluate the effectiveness of existing methods?

Keywords, synonyms and search strategy

The following keywords were chosen for driving the SRL, considering the usually techniques therms and pest scientific and popular name: (K.1) computer vision; and (K.2) deep learning; (K.3) neural networks; (K.4) image processing; (K.5) image classification; (K.6) plague detection; (K.7) whiteflies; (K.8) bemisia tabaci; (K.9) plant disease.

The general logic search string was defined as (”Computer vision” OR ”Deep learning” OR ”Neural networks” OR ”Image processing” OR ”Image classification”) AND (”Plague detection” OR ”Whiteflies” OR ”Bemisia tabaci” OR ”Plant disease”).

This string was adjusted for every electronic database in order to meet its search syntax. We searched on five databases: (1) ACM Digital Library; (2) IEEE Digital Library; (3) ISI Web of Science; (4) Science Direct; and (5) Scopus, since they gather most of the publications on the area of computer science and applications.

Inclusion/Exclusion criteria

Inclusion and exclusion criteria were defined for guiding the selection of primary studies relevant to the SRL. A study was included if it was: (1) available in full-text; (2) published in a journal or in the annals of a conference; (3) a technical report, including surveys; or (4) a master dissertation or a doctoral thesis. On the other hand, it was excluded if it: (1) was not written in English; (2) was published before 2008; (3) present evaluations without describing the used method; (4) do not use digital image processing techniques; (5) do not use digital image processing techniques for the whitefly pest detection.

A set of Yes/No/Partially quality assessment questions was also defined based on a refinement of the main research questions (RQs). For instance, they asked if the classification methods or techniques have been objectively reported or if there is an application or final product, has it been described in detail.

Conducting the review

The proper search strings, with the corrected search conditions, were applied to the databases. Next, as a Study Selection step, the bibliographic references were evaluated according to the inclusion and the exclusion criteria (with the help of the SRL software platforms). When necessary, the full text of the studies was consulted. Table 1 summarizes the number of papers recovered when searching in each database, and the amount of accepted (selected), reject and duplicate studies during the Selection step. In Total, 25 studies were accepted.

Table 1: Number of studies in the SRL.

Database	Total	Accepted	Rejected	Duplicated
ACM DL	103	4	82	17
IEEE DL	94	3	89	2
WebOfScience	129	5	69	55
ScienceDir	81	9	64	8
Scopus	31	4	12	15

The studies were included according to the inclusion and exclusion criteria, and in addition, the following quality criteria were applied: (1) Have classification methods or techniques been objectively reported?; (2) Were the methods of acquisition and preprocessing explicitly cited?; (3) Was the technique used compared to other existing techniques?; (4) Is there an evaluation of this technique?; (5) If there is an application or final product, has it been described in detail?.

These criteria were elaborated based on the research questions and for each criterion a value was assigned in conjunction with a concept: Yes (S) = 1 point, No (N) = 0 and Partially (P) = 0.5, where the junction of all the criteria form an index that was classified as follows, works with index between 0 and 1 were considered very bad, indexes between 1.5 and 2 were considered bad, works between 2.5 and 3 were considered good, between 3.5 and 4 work was considered very good, and the works that obtained between 4.5 and 5 were considered excellent. The value of the index indicated the priority for reading the articles and was also a factor for the exclusion of articles if the work has a very low index and there is no specific contribution, which would justify the low index. After the quality assessment, 21 studies were selected for full read.

Next, we describe the main concepts in some of the studies selected by the SRL.

RESULTS AND DISCUSSION

Barbedo (2014) explains there are two main strategies for automatically counting whiteflies found in the literature, one using sticky traps, and the other using plant leaves directly. In sticky traps images, only specimens capable of flying are considered, in leaves images early stages like nymphs can be considered.

Sticky traps images

Sticky traps consist of glue cards where the specimens are attracted by the color of the paper and are caught by the sticky substance, the smooth and neutral surface make the counting easier.

Cho et al. (2008) proposed a method to explores size and color features to identify and count whiteflies, aphids and thrips, using color transformations, simple mathematical morphology operations, and thresholding. Boissard, Martin e Moisan (2008) proposed a cognitive vision system that combines image processing, neural learning and knowledge-based techniques to detect and count pests. Qiao et al. (2008) described a image processing system to estimate the population of adult specimens of whiteflies collected on sticky traps based on size and color. Bechar et al. (23-2) uses techniques like Mixture-of-Gaussians and Principal Component Analysis to extract small spots present on the scene and detect whiteflies in sticky traps in a real-time system. Solis-Sánchez et al. (2011) developed a new algorithm capable to detect and identify five species, including whitefly, using geometrical characteristics of insects that affect greenhouse. Barbedo (2014) presented a new method for counting whiteflies on soybean leaves based on conventional digital image, the algorithm is capable of detecting and quantifying not only adult whiteflies, but also nymphal specimens using region-of-interest (ROI) delineation, application of color transformations, threshold-based segmentation, and detection of young nymphs. Xia et al. (2015) used watershed algorithm and Mahalanobis distance on YCrCb color space, to propose a pest identification procedure, for low resolution images in sticky traps using portable devices. Espinoza et al. (2016) proposed a novel approach for the detection and monitoring of adult-stage whitefly (*Bemisia tabaci*) and thrip (*Frankliniella occidentalis*) in greenhouses based on the combination of an image-processing algorithm and artificial neural networks and described a new range of possibilities with the improvement of neural networks in the last years. Sun et al. (2017) proposed a technique rather than directly counting the pests captured on the traps, the concept is to treat trapped pests as noise in a two-dimensional (2D) image with 2DFT serving as a specific noise collector.

Plant leaves images

These approach consists on take pictures directly on leaves surface in greenhouse or open fields, the main difficult is that leaves imperfections and open field climatic disturbances make counting harder.

Huddar et al. (26-2) proposed a method capable of counting insects not only in greenhouses, but also in open farms, the algorithm has four steps: color conversion, segmentation based on the relative difference in pixel intensities, noise reduction by erosion, and counting based on Moore neighbor tracing and Jacob's stopping. Li, Xia e Lee (2015) proposed new application of multifractal analysis for the detection of small-sized pests (e.g., whitefly) from leaf surface images *in situ*. Multifractal analysis was adopted for segmentation of whitefly images based on the local singularity and global image characters with the regional minima selection strategy. Maharlooei et al. (2017) presented the use of digital imaging technique to detect and count soybean aphids on soybean leaves. Lino et al. (18-2) made a comparison between the performances of LBP and Haar features in a Cascade Classifier, which aims automatically to count immature whiteflies (nymphs). Jige e Ratnaparkhe (19-2) presented an algorithm for automatic detection and counting of whiteflies in images of cotton plantations, the algorithm uses color space conversion, background subtraction, threshold operation, morphological operation and counting of the whitefly number on the leaf with centroid algorithm and region properties. Fuentes et al. (2017) proposed a detector based on neural networks for real-time tomato diseases and pest recognition, including the whitefly pest in tomato plant images. The objective was to find the neural network architecture best suited for the task and three types of detectors were considered: one using Faster Region-based Convolutional Neural Network (Faster R-CNN), another using Region-based Fully Convolutional Network (R-FCN), and the latest Single Shot Multibox Detector (SSD). Chen et al. (2018) presented an image processing method using CNN to segment and count aphid nymphs on leaves. Wang et al. (2018) proposed a cognitive segmentation approach to pest images. The method works in the follow way. First, a pest image is divided into blocks via an image block processing method. Second, an adaptive learning algorithm is used to accurately select the initial cluster centers. Third, preliminary segmentation results are achieved using K-means clustering. Finally, three digital morphological features of an ellipse are adopted to remove leaf veins. Gutierrez et al. (2019) presented the development and comparison of two different approaches for vision based automated pest detection and identification, using learning strategies. A solution that combines computer vision and machine learning is compared against a deep learning solution. The main focus of his paper is on the selection of the best approach based on pest detection and identification accuracy.

CONCLUSIONS

Based on the SRL, we found that in the last ten years a few studies was conducted on whitefly pest detection, average two papers per year are published for this purpose. In the sticky traps approach the main difficulty related are detecting whiteflies caught at the edge of the trap, where it is relatively difficult for the image processing system to detect them. In the leaves images, the most related difficulty is detecting early stages nymphs and classify the different stages.

As future work, it is suggested the use of nymphs detection techniques used in other species, such as aphids for the detection of whiteflies nymphs and could be interesting to see how these techniques could be improve in open field in images acquired in mobile devices. An automatic solution for use by farmers and field researchers could be proposed, deep learning techniques has become popular and is also an alternative in embedded technologies. There is no open dataset available and those reported in papers, show the scarcity of images and data for this field.

Despite these challenges, the field presents promising results and has followed the evolution of digital image processing techniques in agriculture.

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REFERENCES

BAR, L. et al. Downregulation of dystrophin expression in pupae of the whitefly bemisia tabaci inhibits the emergence of adults. *Insect Mol Biol*, John Wiley & Sons, Ltd (10.1111), v. 0, n. 0, jul. 2019. ISSN 0962-1075. Disponível em: <https://doi.org/10.1111/imb.12579>.

BARBEDO, J. G. A. Using digital image processing for counting whiteflies on soybean leaves. *Journal of Asia-Pacific Entomology*, v. 17, n. 4, p. 685–694, dez. 2014. ISSN 1226-8615. Disponível em: <http://www.sciencedirect.com/science/article/pii/S1226861514000855>.

BECHAR, I. et al. On-line video recognition and counting of harmful insects. In: *2010 20th International Conference on Pattern Recognition*. [S.l.: s.n.], 23–2. p. 4068–4071. ISSN 1051-4651.

BOISSARD, P.; MARTIN, V.; MOISAN, S. A cognitive vision approach to early pest detection in greenhouse crops. *Computers and Electronics in Agriculture*, v. 62, n. 2, p. 81–93, jul. 2008. ISSN 0168-1699. Disponível em: <http://www.sciencedirect.com/science/article/pii/S0168169907002256>.

CHEN, J. J. et al. Automatic segmentation and counting of aphid nymphs on leaves using convolutional neural networks. In: . [S.l.: s.n.], 2018.

CHO, J. et al. Automatic Identification of Tobacco Whiteflies, Aphids and Thrips in Greenhouse Using Image Processing Techniques. In: Anninos, P and Pham, T and Grebennikov, A (Ed.). *MABE'08: PROCEEDINGS OF THE 4TH WSEAS INTERNATIONAL CONFERENCE ON MATHEMATICAL BIOLOGY AND ECOLOGY*. [S.l.: s.n.], 2008. (Mathematics and Computers in Science and Engineering), p. 74+. ISBN 978-960-6766-32-9. ISSN 1792-4308. 4th WSEAS International Conference on Mathematical Biology and Ecology, Acapulco, MEXICO, JAN 25-27, 2008.

ESPINOZA, K. et al. Combination of image processing and artificial neural networks as a novel approach for the identification of bemisia tabaci and frankliniella occidentalis on sticky traps in greenhouse agriculture. *Computers and Electronics in Agriculture*, v. 127, p. 495–505, set. 2016. ISSN 0168-1699. Disponível em: <http://www.sciencedirect.com/science/article/pii/S0168169916304823>.

FUENTES, A. et al. A robust deep-learning-based detector for real-time tomato plant diseases and pests recognition. In: *Sensors*. [S.l.: s.n.], 2017.

GUTIERREZ, A. et al. A benchmarking of learning strategies for pest detection and identification on tomato plants for autonomous scouting robots using internal databases. *Journal of Sensors*, Department of Chemistry and Biochemistry, Faculty of AgriSciences, Mendel University, Brno, Czech Republic, v. 2019, n. 5219471, 2019. Disponível em: <https://www.hindawi.com/journals/js/2019/5219471/>.

HUDDAR, S. R. et al. Novel algorithm for segmentation and automatic identification of pests on plants using image processing. In: *2012 Third International Conference on Computing, Communication and Networking Technologies (ICCCNT'12)*. [S.l.: s.n.], 26–2. p. 1–5.

JIGE, M. N.; RATNAPARKHE, V. R. Population estimation of whitefly for cotton plant using image processing approach. In: *2017 2nd IEEE International Conference on Recent Trends in Electronics, Information & Communication Technology (RTEICT)*. [S.l.: s.n.], 19–2. p. 487–491.

KAMILARIS, A.; PRENAFETA-BOLDú, F. X. Deep learning in agriculture: A survey. *Computers and Electronics in Agriculture*, v. 147, p. 70–90, abr. 2018. ISSN 0168-1699. Disponível em: <http://www.sciencedirect.com/science/article/pii/S0168169917308803>.

KITCHENHAM, B.; CHARTERS, S. *Guidelines for performing Systematic Literature Reviews in Software Engineering*. 2007.

LI, Y.; XIA, C.; LEE, J. Detection of small-sized insect pest in greenhouses based on multifractal analysis. *Optik - International Journal for Light and Electron Optics*, v. 126, n. 19, p. 2138–2143, out. 2015. ISSN 0030-4026. Disponível em: <http://www.sciencedirect.com/science/article/pii/S003040261500409X>.

LINO, A. F. S. et al. Performance of haar and lbp features in cascade classifiers to whiteflies detection and counting. In: *2017 CHILEAN Conference on Electrical, Electronics Engineering, Information and Communication Technologies (CHILECON)*. [S.l.: s.n.], 18–2. p. 1–6.

MAHARLOOEI, M. et al. Detection of soybean aphids in a greenhouse using an image processing technique. *Computers and Electronics in Agriculture*, v. 132, p. 63–70, jan. 2017. ISSN 0168-1699. Disponível em: <http://www.sciencedirect.com/science/article/pii/S0168169916310791>.

MALLETT, R. et al. The benefits and challenges of using systematic reviews in international development research. *Journal of Development Effectiveness*, Routledge, v. 4, n. 3, p. 445–455, set. 2012. ISSN 1943-9342. Disponível em: <https://doi.org/10.1080/19439342.2012.711342>.

MOHANTY, S. P.; HUGHES, D. P.; SALATHé, M. Using deep learning for image-based plant disease detection. *Frontiers in Plant Science*, v. 7, p. 1419, 2016. ISSN 1664-462X. Disponível em: <https://www.frontiersin.org/article/10.3389/fpls.2016.01419>.

QIAO, M. et al. Density estimation of bemisia tabaci (hemiptera: Aleyrodidae) in a greenhouse using sticky traps in conjunction with an image processing system. *Journal of Asia-Pacific Entomology*, v. 11, n. 1, p. 25–29, mar. 2008. ISSN 1226-8615. Disponível em: <http://www.sciencedirect.com/science/article/pii/S1226861508000071>.

SAXENA, L. P.; ARMSTRONG, L. A survey of image processing techniques for agriculture. In: . [S.l.: s.n.], 2014.

SCHWARTZMAN, A. et al. Image processing, computer vision, and deep learning: new approaches to the analysis and physics interpretation of lhc events. *Journal of Physics: Conference Series*, IOP Publishing, v. 762, p. 012035, out. 2016. ISSN 1742-6596. Disponível em: <http://dx.doi.org/10.1088/1742-6596/762/1/012035>.

SOLIS-SáNCHEZ, L. O. et al. Scale invariant feature approach for insect monitoring. *Computers and Electronics in Agriculture*, v. 75, n. 1, p. 92–99, jan. 2011. ISSN 0168-1699. Disponível em: <http://www.sciencedirect.com/science/article/pii/S016816991000195X>.

SUN, Y. et al. A smart-vision algorithm for counting whiteflies and thrips on sticky traps using two-dimensional fourier transform spectrum. *Biosystems Engineering*, v. 153, p. 82–88, jan. 2017. ISSN 1537-5110. Disponível em: <http://www.sciencedirect.com/science/article/pii/S1537511016303439>.

VIBHUTE, A.; , S. K. B. . *Application of Image Processing in Agriculture: A Survey*. [S.l.: s.n.], 2012. 34–40 p.

WANG, Z. et al. A cognitive vision method for insect pest image segmentation. *IFAC-PapersOnLine*, v. 51, n. 17, p. 85–89, jan. 2018. ISSN 2405-8963. Disponível em: <http://www.sciencedirect.com/science/article/pii/S2405896318311820>.

WOLFERT, S. et al. Big data in smart farming - a review. *Agricultural Systems*, v. 153, p. 69–80, maio 2017. ISSN 0308-521X. Disponível em: <http://www.sciencedirect.com/science/article/pii/S0308521X16303754>.

XIA, C. et al. Automatic identification and counting of small size pests in greenhouse conditions with low computational cost. *Ecological Informatics*, v. 29, p. 139–146, set. 2015. ISSN 1574-9541. Disponível em: <http://www.sciencedirect.com/science/article/pii/S1574954114001228>.