Computers and Electronics in Agriculture 153 (2018) 69–81

Contents lists available at ScienceDirect

Computers and Electronics in Agriculture

journal homepage: www.elsevier.com/locate/compag

Review

Computer vision and artificial intelligence in precision agriculture for grain crops: A systematic review

Diego Inácio Patrício[a,*], Rafael Rieder[b]

[a] Brazilian Agricultural Research Corporation, Embrapa, Passo Fundo, Rio Grande do Sul, Brazil
[b] Graduate Program in Applied Computing (PPGCA), Institute of Exact Sciences and Geosciences (ICEG), University of Passo Fundo (UPF), Passo Fundo, Rio Grande do Sul, Brazil

ARTICLE INFO

Keywords:
Computer vision
Artificial intelligence
Precision agriculture
Systematic review

2018 MSC:
00-01
99-00

ABSTRACT

Grain production plays an important role in the global economy. In this sense, the demand for efficient and safe methods of food production is increasing. Information Technology is one of the tools to that end. Among the available tools, we highlight computer vision solutions combined with artificial intelligence algorithms that achieved important results in the detection of patterns in images. In this context, this work presents a systematic review that aims to identify the applicability of computer vision in precision agriculture for the production of the five most produced grains in the world: maize, rice, wheat, soybean, and barley. In this sense, we present 25 papers selected in the last five years with different approaches to treat aspects related to disease detection, grain quality, and phenotyping. From the results of the systematic review, it is possible to identify great opportunities, such as the exploitation of GPU (Graphics Processing Unit) and advanced artificial intelligence techniques, such as DBN (Deep Belief Networks) in the construction of robust methods of computer vision applied to precision agriculture.

1. Introduction

Grain consumption has grown in recent years as well as growing interest in efficient and sustainable agricultural processes in order to fit consumer demand. According to data from the Food and Agriculture Organization of the United Nations (FAO) (Food, 2012), only in 2014 were harvested 2.9 billion tonnes of the five main grains grown in the world in order of productivity: corn, rice, wheat, soy, and barley.

In agriculture is noteworthy that image processing and computer vision applications have grown due to reduced equipment costs, increased computational power, and increasing interest in non-destructive food assessment methods (Mahajan et al., 2015). The use of these techniques presents advantages when compared with traditional methods based on manual work, however, there are still a number of challenges to be overcome (Barbedo, 2016).

The machine vision usage has grown in recent years to meet the growing demand for fast and accurate methods in monitoring grain production. An example, according to Zareiforoush et al. (2015) was the use of such methods in rice production to raise the quality of the final product and to fit food safety criteria in an automated, economically efficient, and non-destructive way.

Manual methods for grain assessment are challenging even for people who are trained to perform these tasks. Although, one of the main difficulties is the training of these evaluators. There are scarce places prepared to train people with the necessary quality. Another difficulty is the time required to carry out such evaluations, which prevents quickly decision making and large-scale evaluation.

The use of computer vision, near-infrared spectroscopy, magnetic resonance spectroscopy, electronic nose, spectroscopy using the Fourier transform in infrared light, X-ray and hyperspectral images are some of the techniques that can be used to overcome these limitations (Vithu and Moses, 2016). Such techniques, combined with pattern recognition algorithms and automatic classification tools, have been used to deal with the challenge of monitor cultures and analyze food quality.

Machine Learning Algorithms enable you to analyze massive volumes of data, regardless of complexity, quickly and accurately. Its use is already common in many areas such as fraud detection, credit analysis, fault prediction models, image recognition patterns, intelligent spam filters and product quality analysis. However, considering the variety of alternatives, it is essential to know the individual characteristics of each method and the best scenario for its use.

One of the main factors in popularizing the machine learning usage

* Corresponding author.
E-mail addresses: diego.patricio@embrapa.br (D.I. Patrício), rieder@upf.br (R. Rieder).
URLS: http://www.embrapa.br/trigo (D.I. Patrício), http://www.upf.br (R. Rieder).

https://doi.org/10.1016/j.compag.2018.08.001
Received 21 April 2018; Received in revised form 26 June 2018; Accepted 2 August 2018
0168-1699/

Nomenclature

ACM	Association for Computing Machinery
ANN	Artificial Neural Network
BIC	Border/Interior Classification
BOV	Bag of Visual words
BPNN	Back-Propagation Neural Network
CCV	Color Coherence Vector
CDH	Color Difference Histogram
CNN	Convolution Neural Network
CPU	Central Process Unit
DBN	Deep Belief Network
DBN	Deep Belief Networks
DOM	Degree of Milling
DS	Decorrelation Stretching
DSIFT	Dense Scale-invariant Feature Transform
ExGExR	Excess Green - Excess Red
FAO	Food And Agriculture Organization of the United Nations
FV	Fisher Vector
GLCM	Gray Level Co-occurrence Matrix
GPU	Graphic Processing Unit
GW	Gabor Wavelet
HOG	Histogram of Gradients
HSI	Hue, Saturation and Intensity
HSI	Hyperspectral Imaging
ICA	Imperialist Competitive Algorithm
IEEE	Institute of Electrical and Electronic Engineers
PLS-DA	Partial Least Squares Discriminant Analysis
KNN	k-Nearest Neural Network
LAP	Localized Angular phase
LBP	Local Binary Pattern
LED	Light Emit Diode
MCW	Marker Controlled Watershed
METS	Minimum Error Threshold Selecting
MLP	Multi Layer Perceptron
MSER	Maximally Stable Extremal Regions
NNI	Neural Network Intensity
PBK	Percentage of Broken Kernels
PCA	Principal Component Analysis
PHOW	Pyramid histograms of visual words
iPLS-DA	Interval Partial Least Squares Discriminant Analysis
PNN	Probabilistic Neural Network
PSR	Pitch Segmentation Recognition
RGB	Red, Green and Blue
RMSECV	Root Mean Square Errors of Cross Validation
SEH	Strutucture Element Histogram
SIFT	Scale-invariant Feature Transform
SLC	Saliency Color Space
SLIC	Simple Linear Iterative Clustering
SMH	Support Vector Machine, Maximally Stable Extremely Regions and Histograms of Oriented Gradient Method
SPA	Successive Projection Algorithm
SSLBP	Square Symmetric Local Binary Pattern
SURF	Speeded-Up Robust Features
SVM	Support Vector Machine
VFD	Volume Fractal Dimension
VFDCA	Volume Fractal Dimension with Canonical Analysis
WDH	Wavelet Decomposed Color Histogram
YCbCr	Luma, Blue-difference and Red-difference Chroma components

was the large-scale use of GPUs (*Graphic Processing Units*). This type of specialized hardware initially developed to meet the rendering needs of digital games, has evolved to expand its use in a generic way in diverse areas such as industry, health, climate, computational modeling. They have high parallel processing capacity due to the presence of high amount of processors cores. Thus, they can offer far superior performance when compared to CPUs (Central Process Unit) depending on the type of process. In addition, the advent of the CUDA programming language, and the inclusion of dedicated hardware to facilitate the parallel programming of these processors help developers in building new applications. In this way, it is possible through the use of GPUs to obtain better solutions to a given problem in a shorter period of time (Kirk and Hwu, 2016).

The union of these three components: computer vision, machine learning, and high-performance computing have been shown to be promising in solving different problems in agriculture. The predictive potential made possible by deep learning, a technique that has gained prominence among the others used in machine learning, will cause a disruptive effect in different segments of the traditional industry as well as agriculture.

Due to the relevance of the subject, several revisions have been produced over the last years with the objective of analyzing the published works available in the literature. Barbedo (2013) presented a review of digital image processing techniques to detect, quantify and classify plant diseases from digital images. Those methods include detection, classification, and quantification. Techniques like support vector machines, fuzzy logic, and neural networks are also evaluated. Zareiforoush et al. (2015) published a systematic review of the opportunities to use computer vision in rice quality inspection. The work focused on the practical aspects of rice processing like head rice yield measurement, the degree of milling, fissure identification, shape and size analysis, color analysis, variety classification, chalkiness and internal damage assessment, root estimation, and spikelet analysis. Vithu and Moses (2016) analyzed published works related to computer vision systems applied in food grain quality evaluation. Among the applications analyzed, this review analyses aspects like identification of foreign matter, insect infestation, microbial infection, and discolored grains. Shah et al. (2016) presents a survey of different image processing and machine-learning techniques used in the identification of rice plant diseases based on images of infected rice plants. The survey is organized in two main parts. The first one deals with image processing tasks like acquisition, preprocessing, segmentation, and feature extraction whereas the second part deals with machine learning tasks. Barbedo (2016) addressed the main challenges in automatic disease identification. Among the topics discussed are the intrinsic and extrinsic factors of the image that could affect the performance of the automatic identification techniques. Kamilaris and Prenafeta-Boldú (2018) review the efforts to employ deep learning techniques in agricultural and food production challenges pointing out that those methods provide high accuracy and outperforms commonly used image processing techniques.

In contrast of the reviews presented earlier, this survey aimed to study how machine vision can be applied to the main cultures of grains in a broad aspect and which techniques can operate in combination with artificial intelligence. The idea is to evaluate, through a systematic review, challenges and techniques of computer vision and artificial intelligence applied in diseases identification and pests infestations detection, grain quality, and phenotyping and phenology. In addition, this review intends to identify gaps and opportunities in order to be an updated reference for future works.

2. Methodology

The present systematic review aims to identify in the literature works related to the use of computer vision and artificial intelligence techniques for the five largest grain crops, considering the total tonnes