Early detection of disease on leaves by image processing

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ABSTRACT

In order to eliminate diseases in agriculture and viticulture, the currently used solution requires massive use of phytosanitary products, dangerous for the environment and the operators.

To respond to agronomic challenges, this study seeks to examine the feasibility of early detection of the presence of disease in plants by using imaging techniques based on specific images: acquisition based on thermal effects and image processing based on texture-color techniques.

Keywords: Disease detection, color space, hybrid spaces, thermal acquisition, France.

1. INTRODUCTION

In the fields of precision agriculture and viticulture, proper management of farms allows both increased efficiency and the reduction of negative environmental impacts. Pesticides used in agriculture are foreign molecules with respect to biological processes and leave residues in nature. They have real consequences on the health of consumers, due to their persistence in products and edible plants (Pingault et al., 2009).

The current desire is to reduce the number of toxic molecules allowed on the market under The "Ecophyto 2018" Plan[1], which implies better control of disease outbreaks. Imaging techniques can help to achieve this compromise, especially intervening in the early detection of disease in plants.

Plants have a particular way of reflecting electromagnetic radiation (Figure 1). This unique characteristic is known as the vegetation's spectral signature. Reflection of vegetation is very low in the blue and red regions of the electromagnetic spectrum, slightly higher in the green region and much higher in the near infra-red.

[1] The "Ecophyto 2018" Plan was launched by French government in 2008 for the reduction of pesticide use over the period 2008 – 2018.

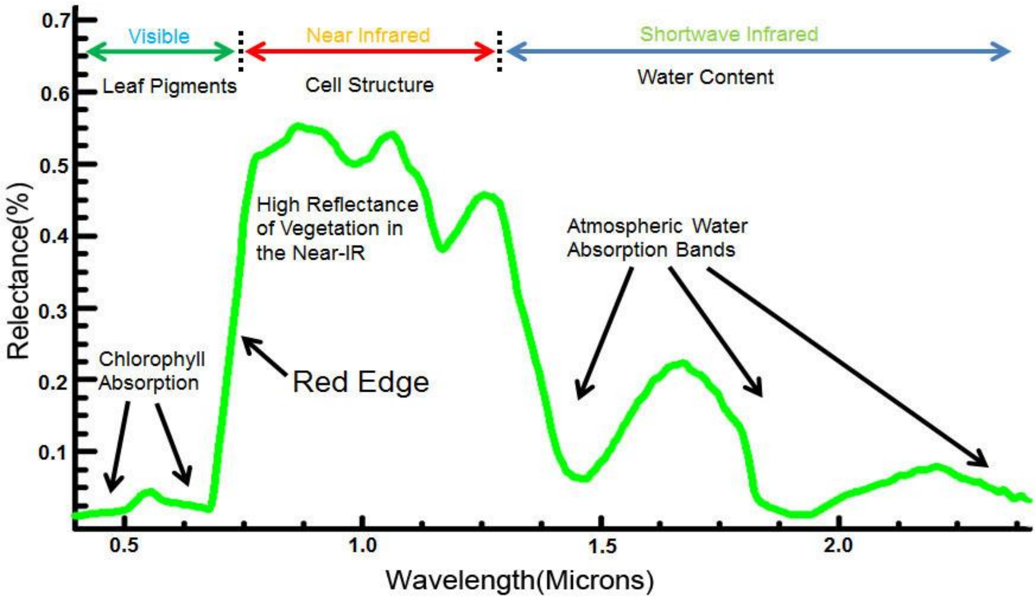


Figure 1. Vegetation Spectrum[2]

The normal growth process of a plant can be disrupted when it goes through a stress period. Thus, it usually expresses certain visible symptoms like color change, but also some that are not visible to the human eye, affecting texture, temperature...

There are several types of stress in plants: water stress, nitrogen stress, pests... All of these tend to affect chlorophyll production, which leads to its loss and the change in leaf color from green to yellow, red and finally brown. These colors constitute the best performing image processing for the detection of disease. However, early detection is a pertinent challenge. Indeed, the onset of disease is reflected in a change of external temperature, external and internal structures, or texture and reflectance of the leaf ... These measurements can be carried out using specific optical systems.

As a first step, we would like to present the algorithms for detecting disease visible or not to the human eye, using techniques based on the representation of images in color spaces, hybrid or not, combining the information concerning both color and texture.

Then we go further, especially if the disease is in an early stage, using NIR (or TIR) acquisitions for visualization.

[2]http://www.markelowitz.com/Hyperspectral.html modified

2. ANALYSIS AND FIRST PROCESSING

Our first studies were carried out on images of vine leaves affected by 'Mildew'. These images represent the different levels of disease areas (Figure 2), and were acquired by photographic sensors.

(a) (b)

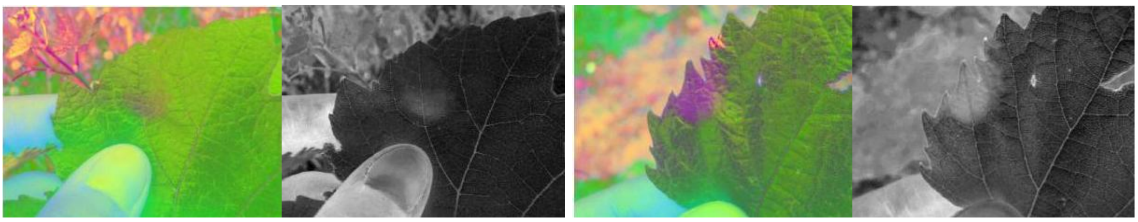
Figure 2. ‘Mildew’ on vine leaves[3] : (a) early stage (b) advanced stage

To undertake the detection of this type of disease, we naturally oriented our efforts towards Color Spaces conversion.

A color space designates the geometric volume corresponding to a set of available colors in a system (Ford et al., 1998). The color space gives additional information, and it represents the correlative relationship between each color. The conversion between color spaces can enhance the color image and simplify the search for the object in the image. The following examples illustrate the detection of the disease ‘Mildew’ on leaves by using this method.

Here, we converted the image of ‘Mildew’ in their YUV color space, Figure 3 represents the two different stages of disease ‘Mildew’' in false color.

In addition, to visualize the spots and facilitate the detection, we focus on different bands of each image. Figure 3 below shows us the V band of the YUV space.



(a) (b)

Figure 3. (a) ‘Mildew’ early stage in YUV color space and V band (b) ‘Mildew’ advanced stage YUV space and V band

[3] Images provided by Sébastien Codis, Researcher, French Vine and Wine Institute. Photographic characteristics unknown.

We easily discern healthy and diseased areas when the ‘Mildew’ is in an advanced stage (Figure 3(b)), the spots of 'Mildew' are clearly visible. But this method does not seem to function well in the case of early-stage disease (Figure 3(a)): this detection is not sufficient to consider adopting color processing alone. It is therefore necessary to combine this method with a processing based on texture analysis.

3. METHODS AND RESULTS

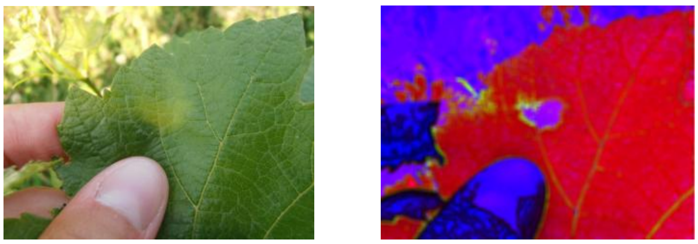
3.1 Hybrid Spaces

In order to detect disease for which the spots are not visible, that is to say when the disease has not yet broken out, but also to simplify the processing and avoid interference of useless color, it seemed promising to use a method of image analysis combining color and texture information.

This method, called "Color - Texture Hybrid Spaces" is based on the determination of a hybrid space of the representation of images combining color and texture information; it was developed in the context of a feasibility study of a system designed to count ears of wheat (Cointault et al., 2008). After determining different classes of points to find, the image is represented in a three-dimensional space: each dimension being a pair of parameters [texture parameter, color parameter].

To test this technique, the example of the image of less visible 'Mildew' Figure 4(a) is used. In this image, three classes of textures can be discerned: the perturbation (background, finger ...), the leaf and the diseased area of the leaf.

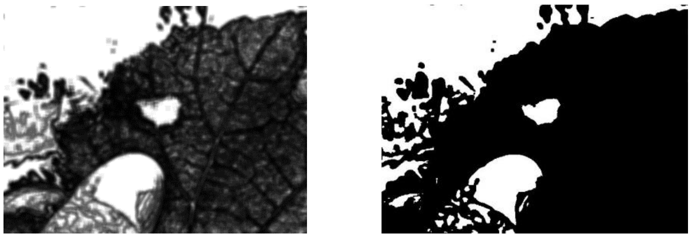
The program allows us to choose 20 learning patches for each class by clicking on the image. We obtain the image shown in the new space in false color Figure 4(b):



(a) (b)

Figure 4. (a) Early stage ‘Mildew’ on vine leaf (b) Representation of the image in the hybrid space

And, using the Mahalanobis distance measure, we obtained the following images of segmentation (Figure 5):



(a) (b)

Figure 5. Segmentations using Mahalanobis distance measure (a) grayscale image (b) binary image

By neglecting the perturbation, segmentation provides a satisfactory result: the diseased area is clearly identified compared to the healthy area of the leaf, the shape corresponds to the disease spot, and this gives us a great advantage in working on the detection of disease in plants.

3.2 Issues

In the previous example (Figure 5), most of the diseased area was detected, but a problem remains: we see a less visible area of disease, which is prolongation of the main diseased area, which has not been detected (Figure 6).

(a)

(b)

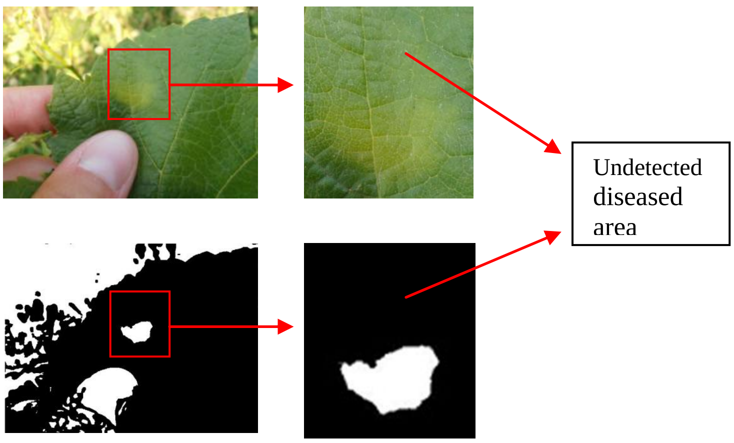


Figure 6. (a) RGB image (b) Segmentation using Mahalanobis distance measure

Effectively, this area has already been attacked by the disease, but it is still in a primary stage, so detection of disease seems impossible using the method of hybrid spaces in this case.

3.3 Thermal imaging

The previous examples show us that when the disease is in an early stage, the method of changing color spaces and the use of the technique of hybrid spaces involving color and texture are not enough to solve this problem. Indeed, if the disease is already visible to the human eye, there is no interest in terms of phytosanitary treatment.

It is therefore necessary to focus on coupling color processing with another technique for image acquisition operating in different spectral lengths.

From the characteristics of plants called 'Spectral Signatures' (Figure 1), we know that when a virus or stress begins to attack the plant, reflectance in the infrared spectral lengths undergoes an important modification.

We can imagine that if you work in the near-infrared spectra, the early detection of disease will be facilitated. Here we have chosen to work on thermal imaging.

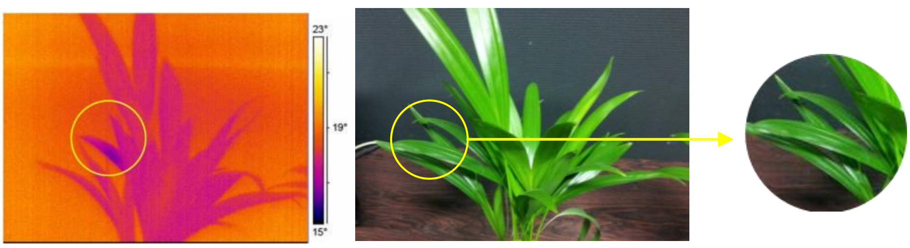
3.3.1 The interest of thermal imaging

In precision agriculture, thermal imaging allows estimation of the amount of chlorophyll present in plant (Chaerle et al., 2006). It gives us an immediate view of the distribution of radiation from the scene observed by the human eye or camera (Pajani, 2012).

Before chlorophyll starts to break down in stressed plants, whatever is causing the stress has already started to affect the cellular structure of the leaves (Guénette, 2003); thermal imaging allows us to observe this change in the near infrared (not visible to the naked eye), even before symptoms begin to appear.

3.3.2 Application and results

The example in Figure 7 illustrates the interest of thermal imaging in our study. The green plant reveals a distinct point in the thermal image in Figure 7 (a): the color of this point is darker than the other areas. From the temperature indicator, we know that the temperature of this unusual point is lower, but we cannot discriminate these differences in RGB image shown in Figure 7 (b).



(a) (b)

Figure 7. Green plant: (a) thermal image[4] (b) RGB image

[4] Image acquired by thermal camera Flir A40, spectral range: 7,5 - 13 µm

Even if we do not know the cause of the drop in temperature of this point, we know that there are changes related to the internal structure of the leaf.

Continuing with this test, we discovered the explanation one week later: Figure 8 shows us that the branch corresponding to this distinct point is withered, the leaves have dried out, water has evaporated, heat has escaped through of perspiration, so the temperature is lower in this area.

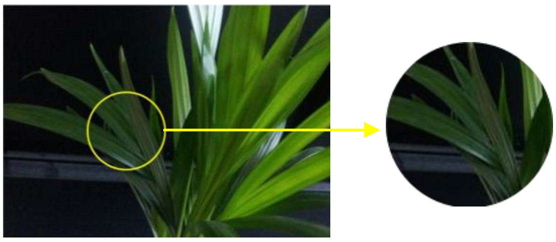


Figure 8. Green plant in an RGB image one week later

Despite the limits of acquisition measure in this experiment (once a week), we can detect problems at least 2 or 3 days earlier than with the other methods presented above. This is a major advantage compared with the methods that we have presented above, because in the color image of this example, there is no change in color or in texture.

This example demonstrates that thermal imaging is efficient in detecting water stress.

4. CONCLUSION AND FUTURE WORK

In this paper, we applied several methods to detect health problems in plants. Processing on color and texture are traditional methods used to meet the demands in this field, but results are not sufficient to consider pursuing a goal of early detection of diseases. Texture characteristics give us the possibility to detect symptoms that are less visible to the human eye.

The use of a thermal camera helps us to discover early symptoms of health problems in plants, because more information is acquired from the source image. This feasibility study has provided results which meet our initial expectations, especially early detection of diseases.

The future of this work is to carry out additional research to identify different diseases, and to discriminate between them. The continued use of thermal information and/or information obtained by means of fluorescence techniques (in process) result in better analysis in this research, and provide the possibility of calculating the infected area.

5. REFERENCES

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