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DEVELOPMENT OF AN AUTOMATIC CONTROL MANAGEMENT SYSTEM FOR A GREENHOUSE

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ABSTRACT This study focuses on rose disease detection. Pests and diseases represent a very important problem for the international trade in cut flowers and foliages and must be controlled. In Mexico, many varieties of flowers are being cultivated, with a total value that reached 387 million US\$ in 2006. Roses are currently the most economically important ornamental crop and are very susceptible to diseases which spread easily. It would be possible to conduct early protection and treatment if plant health could be diagnosed easily and if the causes of their infections were known. In this research a rose disease diagnosis system was developed with Open CV (Open Source Computer Vision). The disease diagnosed was powdery mildew (*Sphaerotheca pannosa*). Then a mask was created using the plant region and was combined with the source image. The combination of these two images permitted the removal of the background. Finally the accuracy of the diagnosis was evaluated. The developed disease diagnosis system is able to diagnose the powdery mildew disease through the HSV space color with Open CV. Better diagnoses were obtained when using close pictures (10cm) where the average coincidence rate was $77.6 \pm 14.1\%$. For distant pictures (50 cm) the coincidence rate obtained was $52.8 \pm 17.1\%$. The misconception rate caused mostly by halation when using distant pictures could be successfully avoided using active sensing which allows for disease diagnoses even when using distant pictures.

Keywords: Leave the word greenhouse cultivation, plant diagnosis, computer vision, greenhouse rose, Open Source Computer Vision Library

INTRODUCTION Nowadays the expanding world flowers trade is considered to be worth an estimated US\$60 billion and over 65 countries are involved in the international trade in cut flowers and foliages. The main markets are located in three main areas: Europe with around US\$30 billion having as suppliers Kenya and Ethiopia; United States with around US\$6.5 billion having as suppliers Colombia, Ecuador, Costa Rica and Mexico, and finally Japan with US\$4 billion having as suppliers Korea and China (Fig. 1). Roses are thought have been cultivated for at least 5,000 years and are currently the most economically important ornamental crop (M. Linde, et al, 2004).

According to the International Association of Horticultural Producers (AIPH) the main countries producing flowers and potted plants by their production values, in 2005, were: United States (US\$ 5.4 billion), the Netherlands (US\$ 4.8 billion) and Japan (US\$ 3.7 billion). The main exporting countries, in the same year, were: the Netherlands (US\$ 3.1 billion), Colombia (US\$ 957.957 million), Kenya (US\$ 322.22 million) and Israel (US\$ 174.174 million). On the other hand, the main importing countries for the same year were: Germany (US\$ 1.06 billion), United States (US\$ 756.41 million) and Japan (US\$ 67.18 million).



Fig. 1 World's flowers market scale (International Statistics Flowers and Plants 2007)

Table 1 Mexico's main agricultural products according to its production value per hectare, in 2006 (SIAP, SAGARPA)

Product	US\$/ha
Flowers	30,952.41
Tomato	11,669.6
Potato	10,306.26
Avocado	7,748.302
Sugar cane	2,382.891
Green alfalfa	2,316.224
Corn	506.8258
Green grass	477.6922
Coffee	462.9505
Sorghum	440.7762

Mexico is one of the principal suppliers of USA. In Mexico the principal products cultivated in 2006 were: corn, sugar cane, grass and grassland, avocado, sorghum, alfalfa, potato, tomato, coffee and flowers whose production value represented 48% of the total

production value in the same year. Flowers represented just 1.67% of the total production value. Nevertheless, flowers were the most important crop for production value per hectare in Mexico in 2006 (Table 1).

In addition, the great diversity of climate and soils in Mexico permits cultivation of many varieties of flowers, whose total value reached \$387 million in 2006. Mexico State is the principal producer of flowers in the country producing around 88% of the total flowers production, and participates with 75% of the national exportation.

The main flowers cultivated in an area of 15 thousand hectares in Mexico from 2004 to 2006 were gladioli, chrysanthemum, marigold, carnation and greenhouse rose representing 33% of the total cultivated area in 2006 and 66% of the of the total production value in the same period.

Greenhouse rose production represented just 1.91% (485.2 ha) of the cultivated surface in 2006 (Fig. 2(a)), but its value corresponded to 18% (around \$76.7 million) of the total production value of the same year (Fig. 2(b)). In addition, greenhouses are increasingly important in flower production. However, pests, diseases and extremes of heat and humidity, have to be controlled.

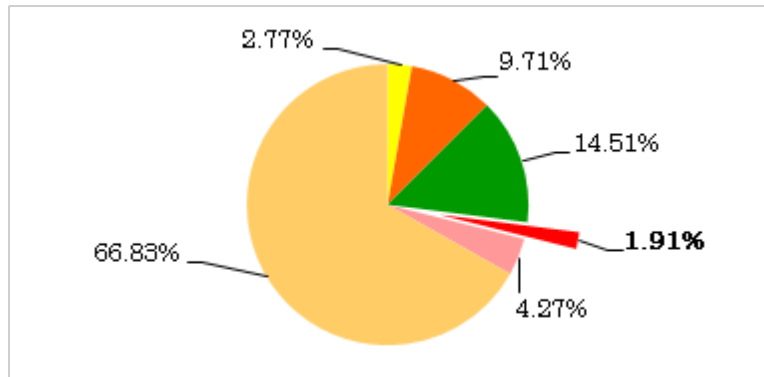
However, the most disease-affected plant family is the rose. Diseases significantly reduce the ornamental value of the plant. These diseases are caused by funguses, bacteria and viruses. Among them, funguses are the most important, representing more than 98% of the cases. It would be possible to conduct early protection and treatment if it could be diagnosed whether plants are healthy or infected as well as the cause of their infection. At the same time, working efficiency and laborsaving efforts have to be improved (in order to ease the work.).

For the reasons given above, the development of an automatic diagnosis technology is very important. The ultimate goal of this research is the development of a total automatic management system for greenhouse cultivation.

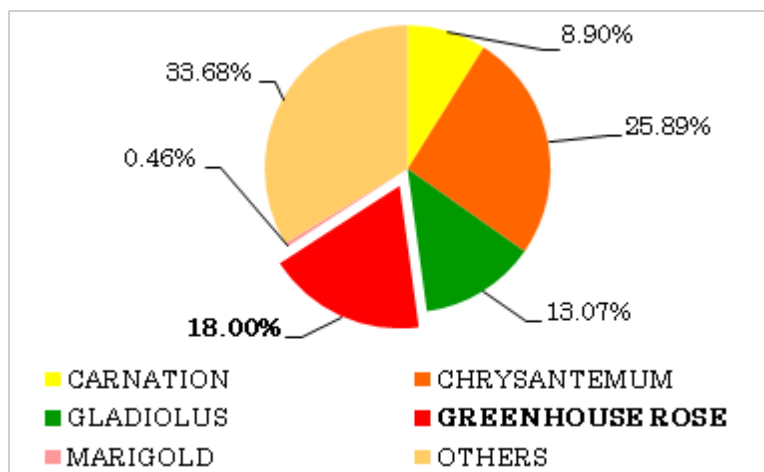
In this paper, the following points have been studied.

1. Development of a disease detection system for greenhouse rose cultivation using image processing with Open CV
2. Evaluation of the developed system

If this diagnosis system is developed, this technology could be applied not only in Mexico but in all the countries producing flowers.



(a) Percentage of cultivated area in Mexico



(b) Percentage of production value in Mexico

Fig. 2 Rose production (SIAP- SAGARPA, 2006)

MATERIALS AND METHODS

Disease and materials Lipstick was the variety infected with the powdery mildew disease, which is caused by the fungus *Sphaerotheca pannosa*. These rose leaf symptoms (Fig. 3) are typical of the powdery mildew infections, with a white powdery-looking growth on the surface of leaves and occasionally bracts and stems. When the fungus is active, severely infected leaves appear almost white. Young leaves may be twisted and curled. Older leaves are not affected as severely. Plants are rarely killed by powdery mildew infections, but leaves and flowers may be smaller and plants unattractive.

The fungus produces spores abundantly on the leaf surface, and they readily infect new sites as long as environmental conditions are conducive to germination. Unlike most

fungal spores, powdery mildew spores do not germinate well in free water. However, they germinate within a couple of hours at high relative humidity and at above 22°C.

Pictures were taken on February 20, 2009, from 12:00hrs to 16:00hrs, in Coatepec Harinas, Mexico State, Mexico. The weather was clear and the temperature inside the greenhouse was around 25°C. Figure 4 shows the outside view [Fig.4 (a)] and the inside view [Fig.4 (b)] of the greenhouse where the pictures were taken. The pictures used in this research were taken with a video camera Everio; Victor.JVC, GZ-HD30. The photograph samples were taken at a distance of 10 and 50 cm. Pictures were taken under two different conditions of background; only soil and soil as well as leaves were included. Sunlight reflection was avoided in order to prevent halation on the pictures. Sample photographs from the surroundings (different angles, directions and distances) of the plant, focusing on the disease parts, were taken also. Finally, pictures of healthy leaves were taken. The Illumination (kLux) was measured during 5 seconds for each place where the pictures were taken with a light-meter CEM (DT-1309) with maximum range of 400,000Lux and the measure rate is 1.5 times/second. In all cases, the image format used was JPG, 24bits and the size of the pictures was 640X480 pixels. The testing set was composed of 40 pictures, 20 pictures from a distance of 50cm (distant pictures) and 20 pictures from 10cm (close pictures).

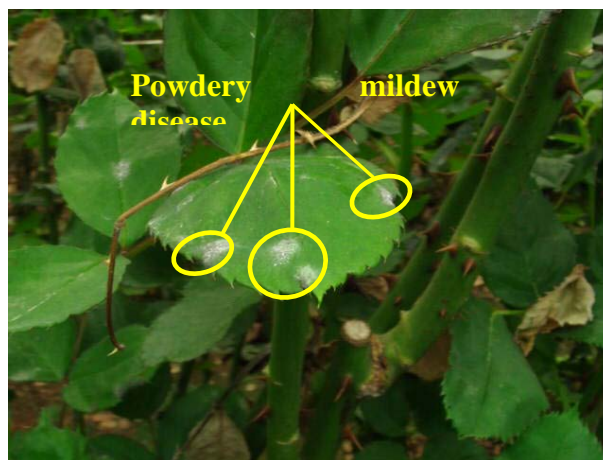


Fig. 3 Rose's leaves infected with powdery mildew



Fig. 3 Greenhouse rose view

Open CV and Image processing method In this research, Open CV (Open source computer vision) was used. Open CV is a free software library supported by different platforms (Windows, Mac OS X, Linux, etc.). It also implements a wide variety of tools for image interpretation. In addition, Open CV provides a set of image processing

functions, as well as image and pattern analysis functions. For example, conversion between the RGB(R:red, G:green and B:blue) and the HSV(H:hue, S:saturation and V:value) space color. The conversion from RGB to HSV allows for the extracting of specific parts or colors from the images, because the source image is divided in three channels (H, S and V). HSV are defined mathematically by transformations between the R, G, and B coordinates of colors in RGB space and the H, S, and V coordinates of the HSV space. Conversion from RGB to HSV space color is represented by the following formulas (Smith, 1978.):

$$H = \begin{cases} 60 \cdot \frac{G - B}{\max(R, G, B) - \min(R, G, B)} + 0 & \text{where } \max(R, G, B) = R \\ 60 \cdot \frac{B - R}{\max(R, G, B) - \min(R, G, B)} + 120 & \text{where } \max(R, G, B) = G \\ 60 \cdot \frac{R - G}{\max(R, G, B) - \min(R, G, B)} + 240 & \text{where } \max(R, G, B) = B \end{cases}$$

$$S = \frac{\max(R, G, B) - \min(R, G, B)}{\max(R, G, B)} \quad (1)$$

$$V = \max(R, G, B)$$

The value of H is generally normalized to lie between 0 and 360°. The direction of each radius corresponds to a tint (yellow, green, blue, etc.). Gray scale in the RGB space color is represented as a ramp moving from black to white color. In the HSV space color the gray scale is represented by value (V) moving from 0% (black) and 100% (white). Therefore the plant regions were extracted according to H and V, and disease regions were extracted according to V and S.

Diagnosis system and experiment method The program was developed using Visual Studio 2005 Development Environment (OS; Windows XP). The computer used was a Dell Vostro 1500, CPU; Intel (R) Celeron(R) 1.86GHz, and memory size; 2GB. The diagnosis occurred according to the algorithm of the Fig. 5. First, all the range values of H, V and S for the extraction of the plant and disease regions were fixed as follow; H (40-130°), V (50-100%, 60-100% and 70-100%) and S (0-40%). Afterwards, the source image was converted from the RGB into the HSV space color. The converted image was then segmented, extracting the disease regions according to V (for different ranges) and S. At the same time, the plant regions were extracted according to H and V. After, the noise was removed by closing and labeling. Then a mask was created using the plant region and was combined with the source image. This image was called “Plant image”. The combination of these two images allowed for the removal of the background. Then color was added to the diseased regions and later those regions were added to the plant image in order to obtain the computed disease image.

Fig. 4 Disease diagnosis algorithm

Finally the accuracy of the diagnosis was evaluated. To test the accuracy and performance of the algorithm and the developed program, a master image was created (Fig. 5). In order to create this image, the source image was analyzed visually identifying the regions of the leaf that were considered infected with the disease. Then those regions were painted white in order to fix the areas. Later, the areas of the diseased regions of the master Image and the areas of the diseased regions of the diseased Image were measured. Then both images were overlaid to obtain the coincidence and non-coincidence disease region areas [Fig. 6]. Using these parameters, both, the coincidence and misconception rate were calculated for the different ranges of V (50-100%, 60-100% and 70-100%) for close and distant samples, using the formulas 2 and 3.

$$CR = 100 \times \frac{A_c}{A_t} \quad (2)$$

Where:

CR: Coincidence rate;

Ac: Coincidence area;

At: Human fixed disease area.

$$MCR = 100 \times \frac{A_{nc}}{A_p} \quad (3)$$

Where:

MRC: Misconception rate;

Ac: Non-coincidence area;

Ap: Plant area.

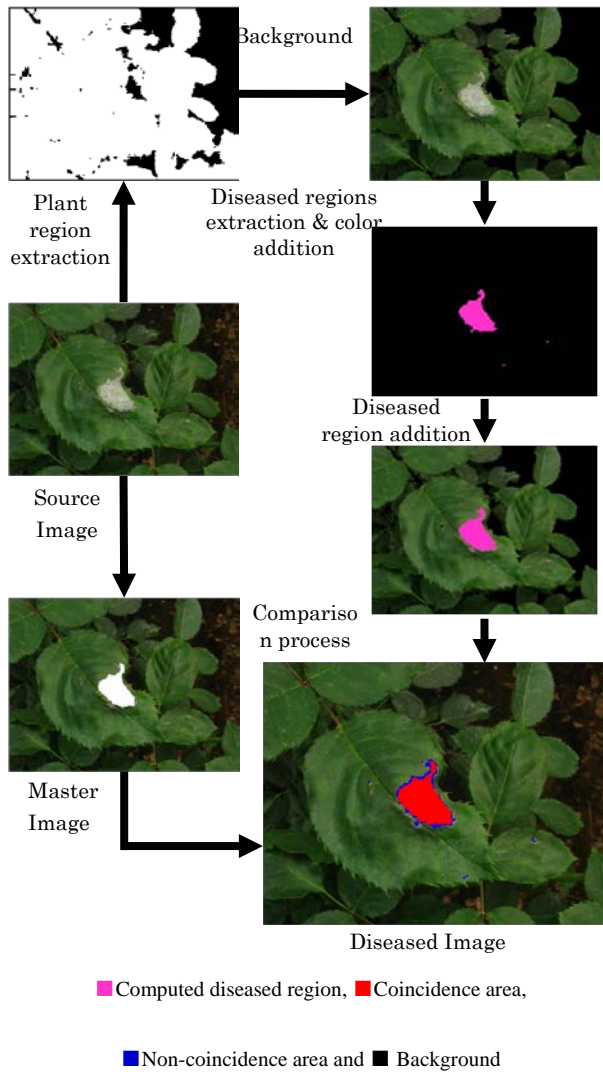


Fig. 5 Diagnosis process

RESULTS AND DISCUSSION

Figure 7 shows an example of a source image [Fig. 7(a)] as well as the plant and disease images [Figs. 7(b) and 7(c)] that were obtained after the image processing.

Fig. 7 also shows the compared image [Fig. 7 (d)] resulting from the comparison between the master Image and the diseased Image (Fig. 6).



(a) Source Image



(b) Plant Image



(c) Computed diseased Image



(d) Compared Image

■ Computed diseased region, ■ Coincidence area,

Fig. 6 Extracted plant and disease regions

In order to ease the recognition of the disease, the extracted disease regions were painted pink and the background was painted black. In the comparison process a color scheme

was used as well. Red was used to represent the coincidence area and blue was used to represent the non-coincidence area [(Fig. 7(d)].

As it is shown in Fig. 7(b) the plant regions were extracted from the source image by eliminating the background. This step permitted the extraction of only the diseased parts that were on the plants and therefore eliminated the noise (white objects) allocated in the background of the source image [Fig. 7(a)].

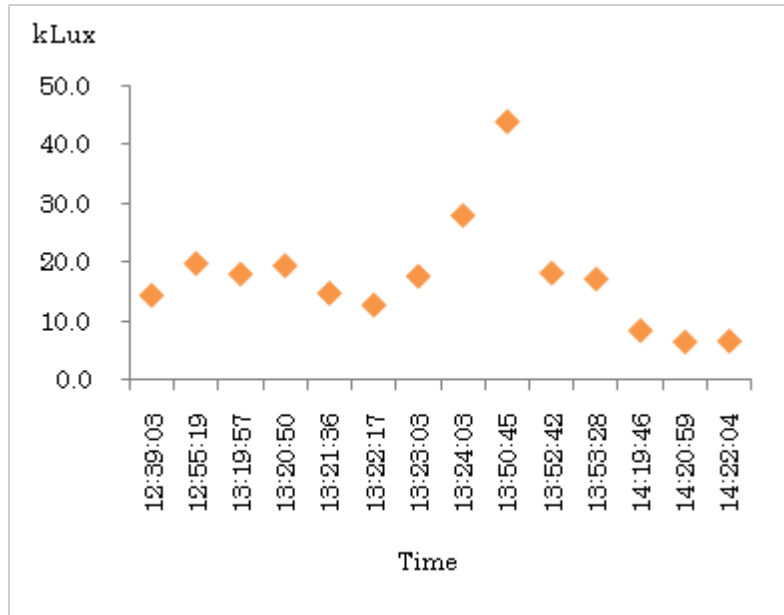


Fig. 7 Light Intensity when taking the pictures