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J.M.Sá da Costa

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Reconhecimento de Padrões.

COLORIMETRIC RECOGNITION IN NATURAL AMBIENT: AN APPLICATION TO HARVESTING

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ABSTRACT

This work is inclosed into the French-Spanish research project "CITRUS-ROBOT". The project consists on the design and elaboration of an autonomous robot able to pick up citrus in natural environments.

The research included in this paper are related with the vision system of the robot. Using the images obtained by a CCD monochrome camera, the system will be able to localize the fruits, in order to provide the coordinates of each one to the robot.

The main problem is the low contrast between the ligth reflected by oranges and leaves. Energetic curves of diffuse reflectance of fruits and leaves have been measured as a function of the frequency. The colorimetric study has allowed the selection of certain interferometric filters that improve the recognition process.

KEYWORDS: robot vision, colorimetric analysis, image processing.

INTRODUCTION

The incorporation of new technologies to agricultural task has been traditionally very difficult and the use of intelligent machines in this area is much more complicated than in the majority of industrial environments. Therefore, the strong international rivalry in this sector, joined to the advances in digital technology, have made feasible the application of this kind of intelligent system.

In this frame, it was since 1987 that a research project named CITRUS-ROBOT has being being developed. The goal of the project is the design and elaboration of an citrus fruit harvesting autonomous robot. This project involves several groups of researchers in both, Spain and France. The research included in this paper are related with it, and they refer to some of the problems associated with the vision system.

The design of an agricultural robot driven by a vision system finds some particular problems of natural ambients. The main of these is the lighting. The only source of light is the sun which suffers from continuous variations depending of the time of the day and the meteorological conditions.

Moreover, the work environment is hard to control. Devoted to solve this problem researchs tend to obtain new methods of growing. Their objective is to make suitable the developing of the trees to the restrictions of automation by stablishing patterns of evolution.

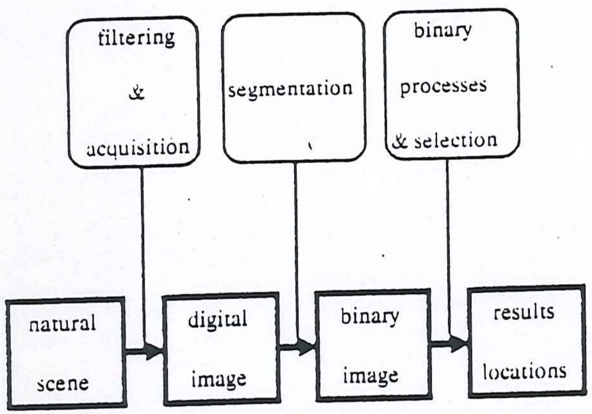
VISION PROCESS

The vision system must be able to localize the fruits in the scene and to indicate their coordinates for their later automatic harvesting by the robot arm. The recognition process is conditioned by two facts:

1) Complexity of the natural scenes to analyze.
Together to the lighting problem refered before, several aditional problems appear. One of them is that the oranges are surrounded by a random background of leaves and branches which frequently produce a partial hiding of fruits. By the other side, the appearing of shadowed zones produced by the tree itself, and the possibility of seeing the sky through the tree, increase the variability of light distribution on the image.

2) Necessity of reaching results in a limited time.
A vision system applied to an automatic process needs certain conditions of effectiveness related to the process time. A commitment between the speed of calculus and the precision of results must be established.

The scheme of the whole vision process is shown:



This paper has as central objective the achievement of an optimal digitalized image which must be the input for subsequent processes. This digital image is a representation in gray levels of the light intensity of the scene, having applied some interferometric filters of certain frequencies.

The colorimetric analysis tries to determinate which of these filters must be used.

COLORIMETRIC ANALYSIS

Due to the problems of ilumination described before, the conversion from a digital monochrome image to a binary image by segmentation techniques gives satisfactory results only if these techniques are applied over images with appropriate lighting conditions, so is said, with uniform lighting conditions.

This only happens when the sky is cloudy or when the sun raises in a particular position.with respect to the camera and to the surface of the tree where the robot is working.

Knowing that the size of the secene taken by the sensor (a CCD camera) is usually about 80 x 60 cm. (31.5 x 23.6 in. aprox.), only fruits, leaves and maybe a piece of sky will be seen in the image. This suggest the necessity of characterizing the elements which form the image.

An analysis of diffuse reflectance of fruits and leaves as the main components of the scene has been done. As it is well known (WYS-82), a light with uniform value in a certain range of frequencies faling upon a surface produces the absorption of a portion of the incident light and the reflection of the rest of the light. The color of the surface of an object depends on the energy reflected for each one of the frequencies.

It is possible to obtain two significant functions that characterize the color of a surface:

$E_R(\lambda)$: spectral distribution of the diffuse reflectance:
$E_A(\lambda)$: spectral distribution of the absorved energy.

Because this paper focuses on the artificial vision and particularly on the detection of fruits in natural ambients, the knwoledge of the spectral distribution of the diffuse reflectance of fruits and leaves will be very useful.

Accurate measurements of diffuse reflectance have been made in order to perform an statistical evaluation. This statistical analysis has as its objective the discrimination between the functions of fruits $E_R(\lambda)$ and the functions of leaves $E_A(\lambda)$, i.e., the color discrimination.

Measurements of reflectance of oranges have been taken, each one corresponding to a different orange. A set of measurements has also been made over both obverse and reverse of the leaves.

Leaves of different ages were selected to elaborate these functions because the color of young leaves is not the same than the color of the old ones; the former are usually brighter. Although the function are similar, the young leaves exhibit an increasing of the values of its diffuse reflected energy.

The following step was the achievement of the patern functions. To make this, the average values of each function at a particular wavelenght was computed (see figure 1). This gave as a result the average spectral distribution function for both fruits and oranges.

The average functions in adittion to their standard desviation are represented together in a diagram (figure 2). It can be noticed that the bands are overlapped at some wavelenghts but are not at other wavelenghts. This implies the existence of certain wavelenghts for which the energetic spectral distribution of fruits and leaves has very separated values.

The function DIF(λ) defined as the substraction between the function of fruits and leaves in the worst case (minimal absolute value) is drawn too. The absolute value of this function shows a maximum at two wavelenghts

680 nm. & 980 nm.

The first wavelenght corresponds to the visible band of the spectrum for which the camera has greater sensibility than the latter corresponding to the infrared band.

These analysis have a great interest for color vision because of the possibilities they offer; but they are also very useful for vision in grey levels as it is shown in the results.

RESULTS

A 680 nm interferometric filter was used in the sensor, and the diaphragm was modified in order to obtain an appropriate range of grey levels.

The used filter is a band-pass filter around the central value. This implies that the grey level in a point of the image depends exclusively on the values of the diffuse reflectance of the object at the wavelenght included in the band. The grey levels of fruits and leaves, with uniform illumination, correspond to the values of the diffuse reflectance at the selected wavelenght in which the difference is shown to be the greatest.

The experimental results confirm that the levels of fruits and leaves are quit separate with the use of this filter, and this improves the segmentation process. As an example of the results, figure 3 is shown.

However, the segmentation process by thresholding (selection of the brightest pixels) finds two problems that must be solved in the binary image. The first is the presence of bright points in the background, due to the reflection of the sunshine on the leaves; the second problem is the case in which the image includes a piece of sky in the border of the scene producing a bright region.

The first problem was solved by a later process consisting on morphological filtering (SER-82) that removed isolated white pixels on a black background. The second one was solved considering that a piece of sky appears habitually in the border and it has a great perimeter. These characteristiques allow to distinguish the pieces of sky from the other elements.

CONCLUSIONS

It has been achieved a method for improvement of an input image in a vision system working with characterized objects. The system will be able to obtain a better segmentation of the images byusing an interferometric filter. It is shown that the best filter which can be used is a 680 nm. filter.

The colorimetric analysis is shown to be useful in both color vision and grey-level vision. Results obtained from filtering are satisfactory and they can be used as input data in later processes.

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ORANGES

Frequency	$E_R(\lambda)$	DS
400.00	11.40	1.37
410.00	11.41	1.41
420.00	11.53	1.37
430.00	11.66	1.40
440.00	11.73	1.45
450.00	11.53	1.15
460.00	11.47	1.14
470.00	12.17	1.78
480.00	12.29	1.65
490.00	11.54	0.83
500.00	12.17	1.13
510.00	14.90	2.28
520.00	18.56	3.04
530.00	23.37	3.70
540.00	28.66	4.50
550.00	33.57	4.53
560.00	38.16	5.05
570.00	44.53	5.47
580.00	49.99	5.42
590.00	54.21	5.39
600.00	57.20	5.44
610.00	59.84	5.48
620.00	61.77	5.62
630.00	63.69	5.82
640.00	65.33	5.76
650.00	66.71	5.97
660.00	67.81	6.01
670.00	68.60	6.11
680.00	69.59	6.17
690.00	70.73	5.97
700.00	71.27	5.59
710.00	71.89	5.46
720.00	72.09	5.33
730.00	72.07	5.28
740.00	72.10	5.26
750.00	72.39	5.51
760.00	72.77	5.51
770.00	73.06	5.49
780.00	73.40	5.44
790.00	73.84	5.38
800.00	74.23	5.44
810.00	74.40	5.30
820.00	74.46	5.26
830.00	74.11	5.15
840.00	73.89	5.19
850.00	73.97	5.25
860.00	73.86	5.09
870.00	73.70	5.06
880.00	73.26	4.84
890.00	72.66	4.86
900.00	71.71	4.85
910.00	70.00	5.00
920.00	68.59	5.26
930.00	66.84	5.10
940.00	64.23	4.92
950.00	60.79	4.82
960.00	57.09	5.29
970.00	55.53	5.67
980.00	55.31	5.88
990.00	55.97	6.10
1010.00	58.97	6.31
1020.00	60.77	6.32
1030.00	62.81	6.25
1040.00	64.79	6.24
1050.00	66.23	6.04
1060.00	67.16	5.94
1070.00	67.44	5.90
1080.00	67.36	5.77
1090.00	66.57	5.54
1100.00	65.34	5.45
1110.00	63.76	5.37
1120.00	61.89	5.20
1130.00	57.81	4.51
1140.00	50.54	4.72
1150.00	44.53	4.97
1160.00	41.43	5.52
1170.00	40.30	5.59
1180.00	39.49	5.43
1190.00	38.43	5.47
1200.00	38.13	5.72

LEAVES

Frequency	$E_R(\lambda)$	DS
400.00	12.76	0.54
410.00	13.05	0.80
420.00	13.36	0.92
430.00	13.59	0.95
440.00	13.79	1.04
450.00	13.71	1.09
460.00	13.93	1.33
470.00	15.18	1.35
480.00	15.31	1.38
490.00	13.80	1.44
500.00	14.85	1.82
510.00	18.69	2.51
520.00	22.45	3.41
530.00	26.15	3.94
540.00	27.91	4.31
550.00	28.72	4.47
560.00	28.12	4.50
570.00	26.40	4.18
580.00	24.17	3.96
590.00	22.98	3.61
600.00	22.39	3.53
610.00	21.49	3.32
620.00	20.33	3.05
630.00	19.89	2.39
640.00	19.22	2.72
650.00	17.61	2.26
660.00	16.60	2.00
670.00	15.24	2.19
680.00	15.03	2.41
690.00	17.83	2.52
700.00	28.55	4.65
710.00	10.57	5.60
720.00	52.04	5.02
730.00	61.51	1.36
740.00	67.36	3.94
750.00	70.42	3.76
760.00	71.72	3.91
770.00	72.23	3.91
780.00	72.55	3.90
790.00	72.82	3.82
900.00	72.99	3.84
810.00	73.20	3.81
820.00	73.46	3.75
830.00	73.58	3.71
840.00	73.81	3.78
850.00	74.16	3.79
860.00	74.41	3.74
870.00	74.59	3.68
880.00	74.83	3.58
890.00	74.82	3.65
900.00	74.64	3.68
910.00	73.78	3.88
920.00	73.36	3.98
930.00	73.50	4.04
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1010.00	74.22	3.99
1020.00	74.69	4.02
1030.00	75.15	4.06
1040.00	75.52	4.04
1050.00	75.95	4.06
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1090.00	76.65	4.09
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1120.00	76.55	3.99
1130.00	76.37	3.92
1140.00	75.45	3.88
1150.00	73.65	3.70
1160.00	72.37	3.73
1170.00	71.78	3.55
1180.00	71.35	3.63
1190.00	71.06	3.63
1200.00	71.07	3.59

Figura 1

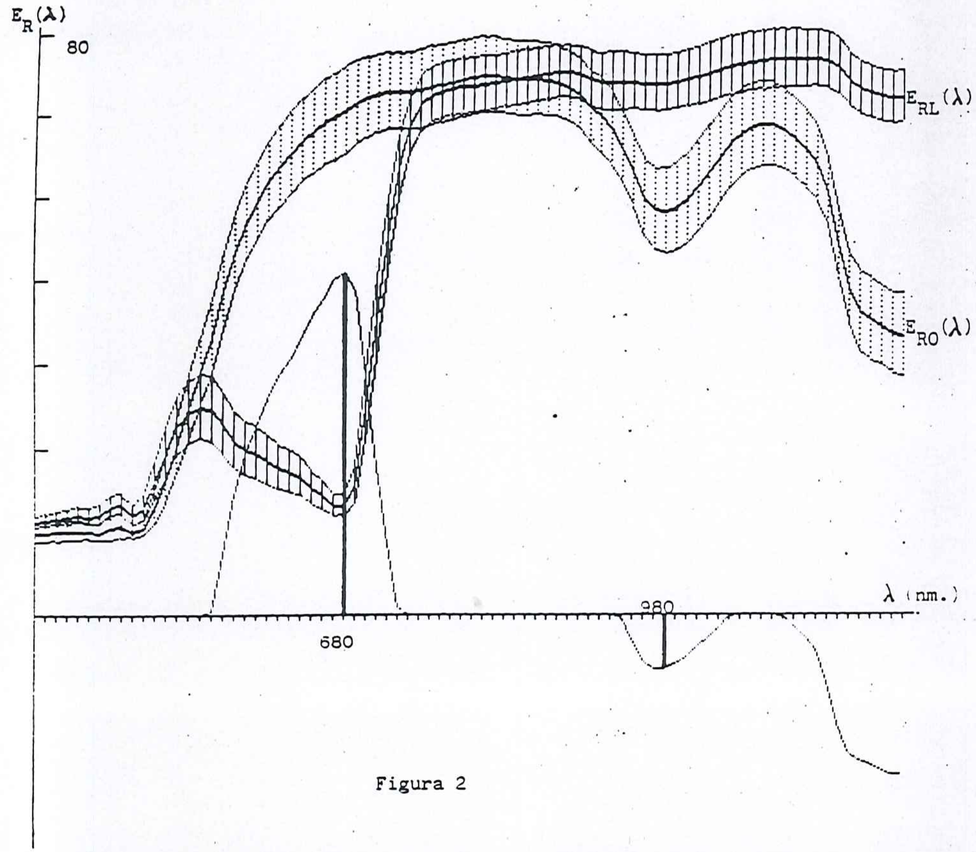

Figura 2

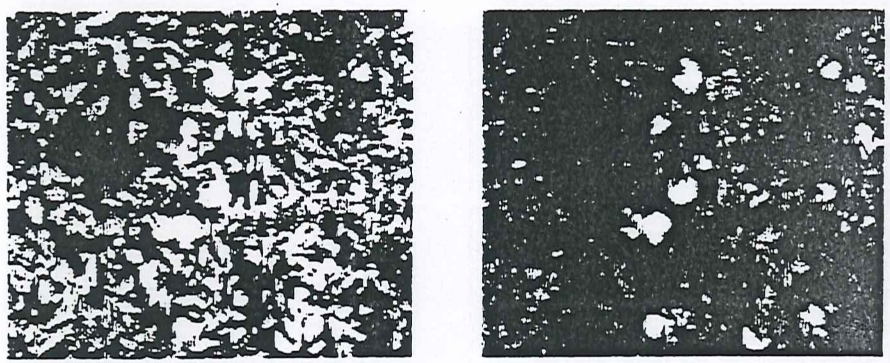

Figura 3

RecPad 90
29-30 Março 1990

Monte da Caparica, 29 de Março de 1990

Caro Participante:

A Comissão Organizadora do RecPad90 deseja-lhe as boas vindas, esperando que o programa da Conferência corresponda às suas expectativas.

Cada Participante vai receber:

- Proceedings.
- Programa definitivo.
- Senhas para os almoços nos dias 29 e 30 de Março de 1990.
- Senha para o jantar da Conferência (caso tenha feito a inscrição) no dia 29 de Março de 1990.
- Mapa do campus da Faculdade de Ciências e Tecnologia.
- Badge identificador.

A lista de Participantes poderá ser solicitada na sexta-feira, 30 de Março de 1990.

A Comissão Organizadora vai por à disposição dos Participantes um autocarro que vai circular com o seguinte trajecto e horário:

- Quinta-feira, 29 de Março de 1990
  Trajecto FCT -> Marquês de Pombal, junto ao Parque Eduardo VII. Partida às 17h15.
- Sexta-feira, 30 de Março de 1990
  Trajecto Marquês de Pombal, junto ao Parque Eduardo VII -> FCT. Partida às 8h45.
  Trajecto FCT -> Marquês de Pombal, junto ao Parque Eduardo VII. Partida às 17h15.

O autocarro pode ser identificado pelo símbolo da Universidade Nova de Lisboa.

Os Participantes poderão também optar por outros tipos de transporte:

- Viatura própria.
- Autocarro RN (direcção Costa da Caparica) com partida da Praça de Espanha (estação de metro Palhavã). Sair no cruzamento das Casas Velhas.
- Taxi.

Durante os dias da Conferência serão servidos almoços assim como café durante os trabalhos. Os cafés serão servidos junto do local onde vai decorrer a Conferência. Os almoços decorrerão no novo edifício dos Serviços Sociais (ver mapa do campus).

O jantar da Conferência está marcado para as 20h do dia 29 de Março no hotel Holiday Inn (Sala Vasco da Gama) em Lisboa (Avenida António José de Almeida, junto ao Instituto

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