

DYNAMIC THRESHOLD SELECTION FOR IMAGE SEGMENTATION OF NATURAL STRUCTURES BASED UPON A PERFORMANCE CRITERION

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ABSTRACT

One of the main tasks in precision agriculture deals with partially or totally unsupervised pesticide treatment of crops plants. To obtain precise plant location, images are usually thresholded to quickly separate foreground or relevant structure from background. Location is required to properly activate an action (spray fertiliser, water or pesticide, make a hole, grasp a weed). This study proposes a fuzzy logic based reasoning system able to dynamically select the best threshold to binarize a grey level image. The proposed algorithm is based upon a performance criterion previously stated that can vary depending on the application at hand. Results are performed on a wide set of real time sequence of images of a field of cauliflowers.

INTRODUCTION.

The need to reduce both the agricultural inputs and the quantity of chemical products has led to the development of precision techniques in many agricultural tasks (Hague et al., 1997), (García-Alegre et al., 2001). One of the main operations in Precision Agriculture deals with treatment of crops plants. To this final aim one necessary step concerns the knowledge of the plants location in the field. Plant location assignment can be automated by means of a computer based vision system devoted to image acquisition and analysis. However, outdoor scenes are particularly laborious to treat in terms of the variability of lighting conditions due to either atmospheric phenomena, day period or season in the year (Batlle et al., 2000).

The real time constraint in natural scenes analysis, points to a reduction in size of the images captured and to a simplification of the algorithmic processing by converting colour or grey level images to black and white images. An immense effort has been addressed to improve these operations in image segmentation. The classical approach uses the grey-level histogram to select the threshold (Otsu, 1979) but the performance is greatly reduced in images with ill defined regions. In these situations, fuzzy sets models have been proposed as a way to embed the uncertainty to improve thresholding (Krishnapuram, 1998).

This study proposes a fuzzy logic based reasoning system, able to dynamically select the best threshold to binarize a grey level image. The proposed algorithm is based upon a performance criterion previously stated that can vary with the application. In the present application the criterion is the emergence of a binary image wherein the analysed structure, cauliflowers, can be easily distinguished by an expert from the rest of the image without losing information.

VISION SYSTEM.

The segmentation algorithm has been developed off-line using sequences of images of cauliflower crops. The crops are transplanted in rows, keeping between both rows and columns a constant distance. This operation generates a grid pattern with one cauliflower on each node.

The images are recorded during the run of a vehicle equipped with a CCD monochrome camera adapted with an infrared filter. Odometry and image analysis are used together to derive guidance information (Marchant et al, 1997). As the image information is required for the vehicle guidance, real time processing and low memory consumption are needed. This real time constraint lead us to work with black and white images instead of grey-level images. The conversion process is achieved by selecting an intensity level, namely the threshold, adequate to separate foreground from background. The position of the cauliflower in the field is to be determined from this binary image. For this reason it is extremely important to use a correct threshold to avoid the loss of some parts of the plant. Due to the huge variety of lighting conditions the most adequate threshold is not a constant, and a dynamic threshold selection is required.

Intelligent reasoning processes such as those performed by human beings in object-directed perception of natural structures, are well adapted to unknown and changing environments. This work tries to emulate the criterion used by humans to select the most appropriate threshold. It is a performance based criterion in the sense that the threshold is considered adequate analysing the emergence of the binary image wherein cauliflowers are easily distinguished from the background and no relevant parts get lost.

FUZZY DECISION SYSTEM.

A wide variety of successful applications have been developed in recent years using fuzzy logic theory, specially those related with classification and control processes where an analytical model is difficult to derive. Fuzzy set theory and fuzzy logic are ideally suited for dealing with uncertainty and imprecision (Krishnapuram, 1998) and (Sugeno, 1985).

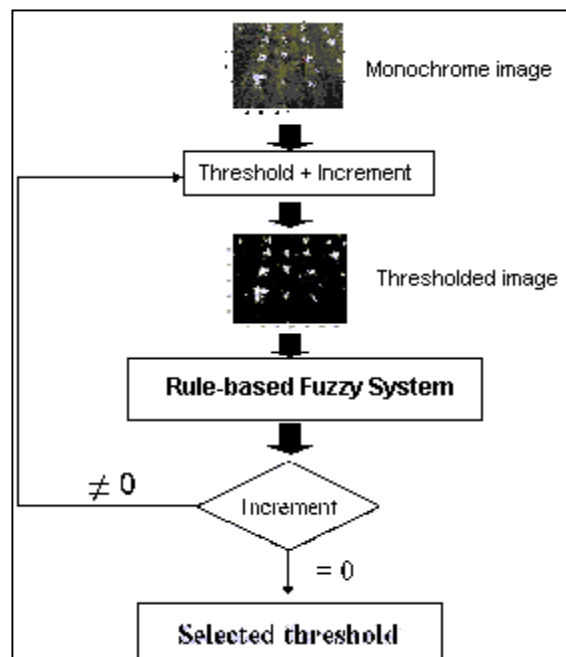


FIGURE 1. Fuzzy decision system.

A fuzzy feedback decision system, Figure 1, has been implemented to perform the threshold selection, dynamically. The system is composed of a set of linguistic expressions of the type: *IF there are few blobs in the image THEN reduce the previous threshold value*. Thus, the rules output provides the variation to be performed on the current threshold to improve the image segmentation.

Variables.

The expert analysis performed on a large set of images has led to the selection of the following fuzzy variables: **Blobs_Number** and **Mean_Blobs_Size** as input variables and **Increment** as the output variable.

Blobs_Number represents the number of blobs in the image. If the threshold is very low, **Blobs_Number** increases as a large background will be considered as foreground. Conversely, if the threshold is too high, **Blobs_Number** decreases as the intensity of some parts of the plants will be below the threshold value and so they would be misclassified as background.

This variable has been modelled as a fuzzy variable with three linguistic labels: {Few, OK, ALot}, where each of them is represented by a trapezoidal membership function, Figure 2. Membership parameters are fixed following a fine-tuning heuristic approach.

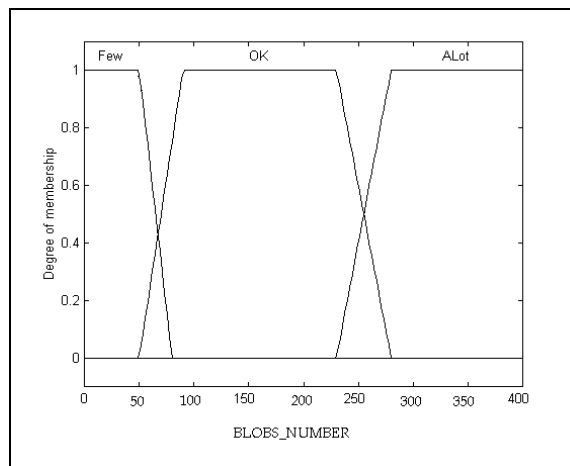


FIGURE 2: Input variable **Blobs_Number**.

Mean_Plant_Size is defined as the mean value of the ten biggest blobs in the image.

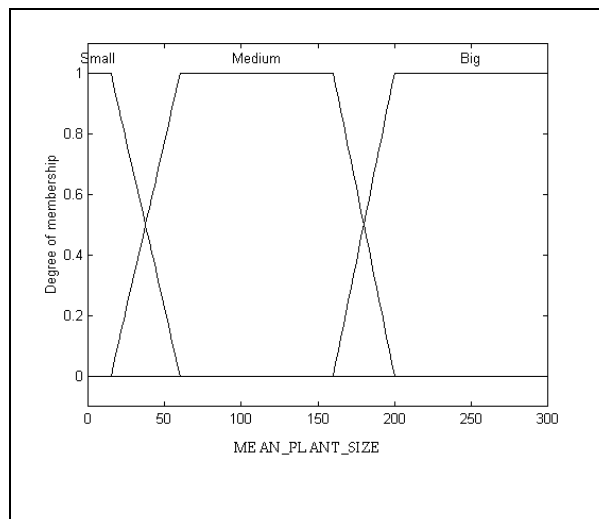


FIGURE 3: Input variable **Mean_Plant_Size**.

This avoids the problem caused by stones and highlights, as the cauliflower is the largest object in the image. When the threshold is too high, parts of the plants are misclassified as background, and this value decreases. The main disadvantage of this criterion concerns the crop variation with the growing stage. Three linguistic labels have been assigned to this value: {Small, Medium, High}, Figure 3. The slope and width of the membership functions are carefully selected after a fine-tuning process.

Increment is the fuzzy variable that defines the increment or decrement that must be applied to the previous threshold in order to improve the segmented image, Figure 4. The threshold is the border between the intensity levels considered as background and those considered as foreground. In this case, having 256 grey-levels, the threshold is an integer value between 0 and 256.

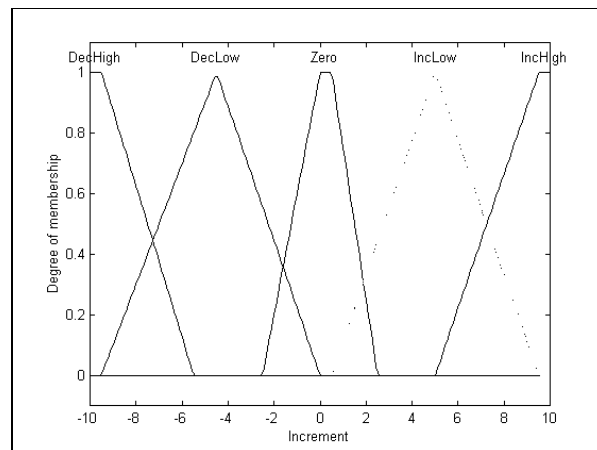


FIGURE 4: Output Variable **Increment**.

Rules.

The criterion for selecting the most appropriate threshold is based on the “goodness” of the segmented image. This is achieved when the image reflects the real world, that means that in the segmented image there are no more objects than those present on the original image and objects maintain their real size.

Current implementation uses the classical maximum and minimum values for the fuzzy conjunction and disjunction operations, respectively. Fuzzy set rules embodying our perception and knowledge to solve the problem, are summarised in Figure 5.

	(1)	(2)	(3)
Bbbs_Number Mean_Plant_Size	Few	OK	ALot
Small	DecrementHigh	Zero	IncrementHigh
Medium	DecrementLow	Zero	IncrementHigh
High	DecrementLow	Zero	IncrementLow

FIGURE 5: Rules Base

The rules set can be divided in three subsets, Figure 5: (1) Rules that imply a decrement in the threshold. This subset contemplates the cases in which the image does not reflect

as many blobs as they really are. (2) Rules in which the threshold is labelled as correct and therefore the variable **Increment** is Zero. (3) Set of rules that makes decision in those cases where the binary image displays more blobs that are present in the real world. The modulating variable **Mean_Plant_Size** decides between a high or a low increment depending on the perceived size.

Defuzzification is performed through the gravity centre algorithm:

$$y = \frac{\int y \mu_0(y) dy}{\int \mu_0(y) dy}$$

Some results are shown in figure 6. The thresholded images reflect properly the scene captured in the grey-level images and cauliflowers can be distinguished from background. In both cases the initial threshold has been modified to adapt better to the image conditions, Figure 7.

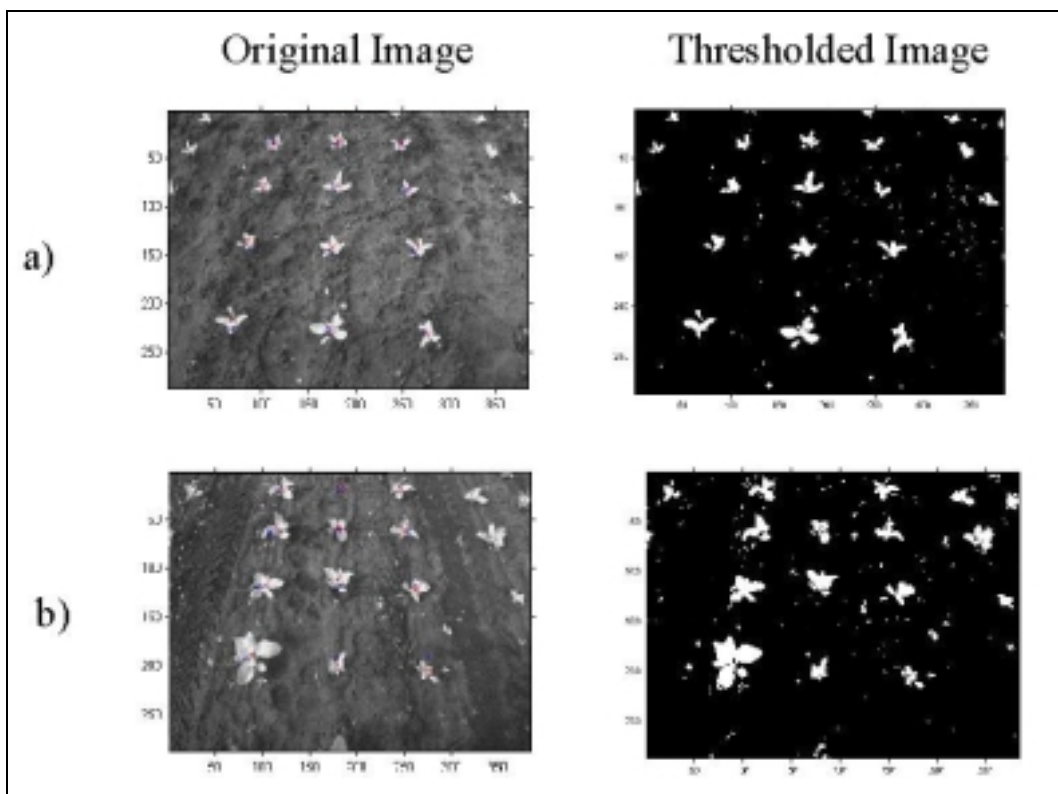


FIGURE 6: Some results.

	StartingThreshold	FinalThreshold
Image a)	160	174
Image b)	165	138

FIGURE 7: Table of results.

CONCLUSIONS

The obtained results show that the fuzzy dynamic thresholding algorithm here proposed present a good adaptation capability to varying lighting conditions. It has been designed to be implemented for real time visual processing in outdoor scenarios.

The fuzzy reasoning algorithms is an adequate and intuitive model to represent the qualitative pattern recognition process accomplished by human experts to get a control decision.

The algorithm has been implemented off-line in Matlab code, but by considering the number of variables, linguistic labels and rules, the expected computing time in C language would be about milliseconds (García-Pérez et al., 2000)

ACKNOWLEDGMENTS

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