THE FUZZY INTEGRAL FOR COLOR SEAL SEGMENTATION ON DOCUMENT IMAGES

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ABSTRACT

The paper presents an application of the fuzzy integral for the selective extraction of color clusters in computer vision systems. The approach is applied on document analysis for the isolation of seals, a task which was till now realized based on shape information. The implemented framework is based on the features of the fuzzy integral as a soft data fusion operator, a concept that is briefly introduced in this work as well. Finally, the framework is successfully tested on a data set formed by documents from a real application for the detection of falsified seals on tax forms.

1. INTRODUCTION

Document analysis is one of the most rapid expanding application fields of computer vision. Administrative, communication and filing procedures, which were till now paper centered, are driven into a digital environment by the ubiquity of different computation facilities. This evolution increases the demands on processing technologies for document images. The here presented algorithm can be used as segmentation stage in a real application that attains the automated analysis of tax forms in custom-houses.

The segmentation of digital images is a long standing research field in image processing. Image segmentation procedures attain the division of the image domain into different regions, whose pixels satisfy a particular perceptual homogeneity condition. Although some applications require the complete segmentation of images as a processing stage, the isolation of a particular feature cluster can be a more suitable goal in other cases, e.g. detection of human presence in video sequences through the segmentation of the skin color cluster.

This paper presents an approach for the segmentation of seals on document color images. The goal of the approach is the detection of the official seal in tax forms in order for the false ones to be identified by the embedding computer vision system. Past works attaining the detection of seals are based on shape analysis [1]. In the here presented approach the color of the seals is taken as the discriminatory feature to segment them from the rest of the document. The approach is based on data fusion by considering the color image as a multisensory signal.

In multisensorial systems the fusion operator reduces the n-dimensionality introduced in the system by the usage of n information sources. Thus the fusion operator is a mean for combining the data coming from different sensors into one representational form [2]. A large number of aggregation operators have been developed in the field of Soft Computing: Uni-norms, OWAs, weighted ranking operators, fuzzy integrals, symmetric sums. These operators are seldom used for image fusion in computer vision applications in spite of its interpretability and flexibility [3].

The selected fusion operator is the fuzzy integral, which has been already successfully applied for image segmentation [4] [5] [6]. Nevertheless the here presented approach differs from these segmentation procedures. It considers the computation of the fuzzy integral with respect to two different fuzzy measures. The fuzzy measures are selected in order for the seal color cluster to present a maximal variation in the two resulting grayvalue images. The described strategy takes advantage of the soft condition of the fuzzy integral as fusion operator. This concept is presented in section 2. Section 3 describes the color cluster extraction algorithm. The results on an evaluation data set obtained from the system for the detection of false seals are analyzed in section 4. Finally the conclusions are given in section 5.

2. SOFT FUSION WITH THE FUZZY INTEGRAL

The fuzzy integral presents the following positive features in front of classical approaches: adaptability, reinforcement capability [7], inclusion of meta-knowledge [7], characterization of the interaction between information sources [8], and tractability of fuzzy information. Moreover, it generalizes both traditionally used fusion operators (e.g. product, sum, minimum, maximum) and other fuzzy aggregation operators (e.g. OWAs, weighted ranking operators) [8] [3].

The Theory of Fuzzy Measures [9] was built on the conclusions made in [10], where the fuzzy integral was introduced. Sugeno meant to make more flexible and robust the fusion operation in order to approximate it to the informa-

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tion binding undertaken by human beings in decision making and subjective evaluation processes. In these processes different criteria are taken into consideration, weighted and thence joint together in order to generate an answer. Three elements capture the flavor of such a process of information fusion: the linguistic expression of the criteria through fuzzy variables, the weighting through fuzzy measures, and the usage of a combination of fuzzy connectives, which are known as T- and S-norms, as operators.

The expression of the different sensor signals, $x_i, \forall i = 1, \ldots, n$, through fuzzy membership functions, which will be characterized here as $h_i(x_i)$, enables the exploitation of the positive features of fuzzy sets for information processing [6]. Furthermore fuzzy features can be represented in a n-dimensional hypercube.

The weighting through fuzzy measures characterizes the *a priori* importance of the different criteria in the fulfillment of the hypothesis being evaluated. Fuzzy measures generalize classical measures by relaxing the additivity axiom of classical measures, i.e. probability measures. Being $\mathcal{X}$ the set of information sources each fuzzy measure coefficient, $\mu(A_j)$, characterizes the *a priori* importance of each subset A_j of $\mathcal{X}$, where $j = 1, \ldots, 2^n - 1$. Thus mathematically the fuzzy measures are functions on fuzzy sets, $\mu : \mathcal{P}(\mathcal{X}) \rightarrow [0, 1]$, satisfying in the discrete case the following conditions : *I.* $\mu\{\emptyset\} = 0$; $\mu\{\mathcal{X}\} = 1$, and *II.* $A_j \subset A_k \rightarrow \mu(A_j) \leq \mu(A_k) \, \forall A_j, A_k \in \mathcal{P}(\mathcal{X})$.

There are basically two types of fuzzy integral known as Sugeno and Choquet Fuzzy Integral. While the Sugeno Fuzzy Integral (S_μ) is the generalization of other ranking operators as the weighted minimum or the median and thus presents a combination of the fuzzy connectives minimum ($\wedge$) and maximum ($\vee$), the Choquet Fuzzy Integral (C_μ) uses a combination of algebraic product and addition becoming a generalization of operators such as the arithmetic mean or the OWAs. The mathematical expressions of these integrals are:

$$S_\mu[x_1, \ldots, x_n] = \bigvee_{i=1}^{n} [h_{(i)}(x_i) \wedge \mu(A_{(i)})] \tag{1}$$

$$C_\mu[x_1, .., x_n] = \sum_{i=1}^{n} h_{(i)}(x_i) \cdot [\mu(A_{(i)}) - \mu(A_{(i-1)})], \tag{2}$$

where $\mu(A_{(0)}) = \mu(\emptyset)$ and the enclosed sub-indices state for the result of a sort operation previous to the integration itself, e.g. if $h_1 \geq h_3 \geq h_2$ then $h_{(1)} = h_1; h_{(2)} = h_3; h_{(3)} = h_2$. This operation fixes up the coefficients of the fuzzy measures employed in the integration, e.g. for the former sorting $\mu(A_{(1)}) = \mu(\{x_1\})$, $\mu(A_{(2)}) = \mu(\{x_1, x_3\})$, and $\mu(A_{(3)}) = \mu(\{x_1, x_2, x_3\})$. Therefore the fuzzy integral defines a different set of weights for each canonical region of the feature hypercube [8], which are defined for the different ranking of the features to be integrated. This extension of the weighting possibilities in a data fusion operator is one of the factors that characterize the process of making a fusion operator "softer" [3].

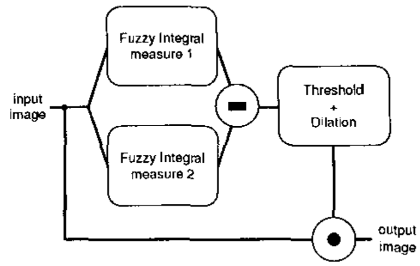

Fig. 1. Block diagram of the here presented framework for the detection of seals on document images. A fuzzy integral is firstly computed with respect to two different fuzzy measures. The change of fuzzy measure mainly affects the seal color cluster. , leaving the other components of the image unmodified. A binary mask image is obtained by subtracting those images, thresholding, and dilating the result.

In this context it is worth summarizing how and what is weighted in different fusion operators. Classical fusion operators have no means of influencing the fusion result. I.e. 2 plus 2 is always 4. Weighted operators, such as the weighted sum, allow taking into consideration *a priori* importance of the values being fused. Furthermore weighted ranking operators like the OWA [7] make the weighting dependent not on the index of the values but on the ranking of the current values. Finally fuzzy integrals apply a different weighting set on each of the possible rankings of the values. Thus it can be stated that the fuzzy integrals improve the flexibility of the fusion operation.

3. SEAL DETECTION BASED ON COLOR

The approach proposed for the detection of seals on document color images is presented in the following. The used strategy considers the computation of the fuzzy integral on the color channels (RGB color space) of the input images with respect to two different fuzzy measures. These are selected in order for the color cluster characterizing the seal to be maximally affected by the change. Thus two grayvalue images are obtained. Thence the difference image of these results is computed and thresholded in order to generate a binary mask. This mask is dilated and used on the input image in order to segment the seal (see Fig. 1).

The methodology can be mathematically described as:

$$I_d(x, y) = \mathcal{F}_{\mu^1}(x, y) - \mathcal{F}_{\mu^2}(x, y), \tag{3}$$

where I_d is the difference image and $\mathcal{F}_{\mu^i}$ states for the images resulting from the computation on each color pixel of

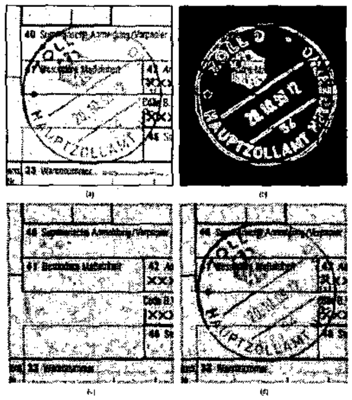

Fig. 2. Exemplary usage of the Choquet Fuzzy Integral for segmentation of seals on a tax form achieved through the here presented framework (see Fig. 1). (a) Input image. (b) Final result. (c) Choquet Fuzzy Integral result with the first fuzzy measure. (d) Choquet Fuzzy Integral result with the second fuzzy measure.

the fuzzy integral (the Choquet or the Sugeno fuzzy integral) with respect to the fuzzy measure μ^i. In the presented examples (see Figs. 2 and 3) the color cluster of the seal is maximally affected by a change in the coefficient $\mu^i(\{x_G, x_B\}) = \mu^i_{GB}$, what was experimentally determined. This fact is a consequence of the position of the bluish color cluster in the canonical region of feature color hypercube where $I_B(x,y) \geq I_G(x,y) \geq I_R(x,y)$. The used strategy exploits in this way the flexibility of the fuzzy integral related to the weighting schemata mentioned in the previous section.

The resulting difference image is finally thresholded and dilated in order to obtain a binary mask for filtering the seal of the rest of the document image. The obtained results on two test images with the Choquet and the Sugeno Fuzzy Integrals are respectively depicted in Fig.2 and Fig. 3.

4. ANALYSIS OF RESULTS

The described methodology was applied on 20 documents from the application at hand, which attains the segmentation of the seals for falsification detection. These documents include a seal that presents the same aspect as the one depicted in Fig. 2. The documents are sampled from real documents, i.e. documents worked out in real offices. Thus they present the seal to be segmented together with different other elements of similar color hue, e.g. pen notations, other seals. Due to a non-disclosure agreement with the enterprise delivering the images, these and the results obtained on them can not be depicted. Therefore the segmentation results are

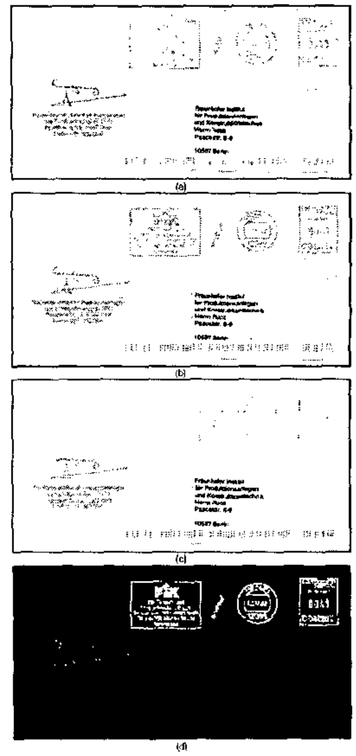

Fig. 3. Exemplary usage of the Sugeno Fuzzy Integral for segmentation of seals on a post letter. (a) Input image. (b) Sugeno Fuzzy Integral result with the first fuzzy measure. (c) Sugeno Fuzzy Integral result with the second fuzzy measure. (d) Final result.

commented on hand of an analytical criteria.

Among the criteria presented in [11] the so-called goodness from region shape is selected. Since the seal to be segmented presents a circular shape (see Fig. 2), an eccentricity coefficient [12] is computed on the obtained difference images (see Fig. 4). The real value of this coefficient, which characterizes shape information, ranges from 0.0 for circular shapes to 1.0 for linear ones. The eccentricity coefficient is rotation, scale, and translation invariant, what compensates for the different position and orientation of the seals in the different images.

The Choquet fuzzy integral outperforms the results of the Sugeno fuzzy integral on the evaluation set due to its some smoother response. The eccentricity coefficient of the difference image (3) is computed for different values of μ^2_{GB} and depicted in Fig. 4. For the sake of comparison two images with artificial errors are added to the data set. Thus a compact area with the same color value as the seal was synthetically added on one of the images. The first dis-

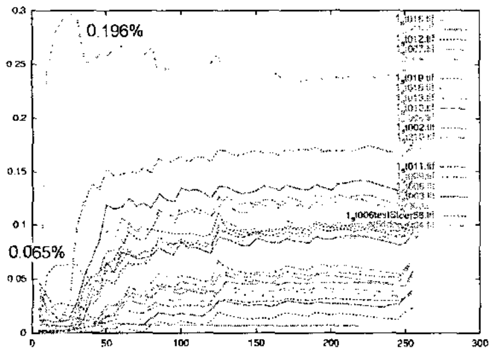

Fig. 4. Eccentricity coefficient [12] for 20 tax forms of a real data set. The coefficient is computed on image resulting from (3) with the Choquet fuzzy integral. The two used fuzzy measures differ in μ^i_{GB}: $\mu^1_{GB} = 0.0$ and $\mu^2_{GB} = i/255\,\forall i = 5, 6, \ldots, 255$ (x-axis). The eccentricity coefficient of three reference images are included for comparison (these are the three last ones in the legend).

turbing region was placed at 180 pixel distance of the seal center and presents an area of 56 pixels (0.065% of the image). The second one was placed at 210 pixels and presents an area of 168 pixels (0.196% of the image). These disturbing regions represent an artificial error in the segmentation with the given percentage.

As it can be observed in Fig. 4 the eccentricity coefficient of all test images are clearly below this of the second reference image (0.196%). Moreover the eccentricity coefficient is relatively constant for the different values of μ^2_{GB}. Thus the automatic determination of this coefficient can be coarsely approached. Taking into consideration this fact the only parameter to be determined in the system remains the threshold for the binarization of the difference image.

5. CONCLUSIONS

The paper presents a simple strategy for the extraction of clusters in the RGB color hypercube. The approach is based on data fusion and uses a fuzzy integral as fusion operator. This fusion operator presents a greater flexibility than operators traditionally used in data fusion applications. For instance the fuzzy integral uses a different set of weights for each canonical region of the hypercube. This property is exploited in the presented application, namely in the segmentation of seals on document color images for the detection of possible falsifications. The approach is successfully applied on an evaluation set of 20 document images taken from real offices. The presented approach can be applied in other fields of computer vision in order to detect particular color clusters, e.g. human skin on video sequences.

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