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A Novel Image Processing Technique for Qualitative Discrimination of Liquids

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***Abstract* — A technique is proposed for automatic qualitative classification of liquid samples. This qualification is based on their absorption spectrum in the ultraviolet, visible and near-infrared regions. . A simple technique based on image matching is proposed to perform pixel comparison. This alternative implementation of conventional image matching methodologies can be easily translated to hardware platforms (Embedded system). The proposed method does not make any assumption on the probability density function of the data and it is also capable of automatic outlier removal. "Spectral marks" based on the polar representation of the absorption spectra and their "optimized marks" improved by means of Radon transform have been implemented.**

***Key Words* — absorption spectroscopy, image matching, Radon transform, spectral shape.**

I. INTRODUCTION

The development of sensor[9] systems able to monitor quality indicators in production processes for the agri food industry are of interest in an era in which quality, origin, etc, could represent an added value to the final product. The improvement of accuracy and time performance could enhance the industrial workflow. There exist some techniques that classify material samples into well-defined groups or categories based on a priori knowledge of the material [1]. A good discriminant algorithm should be capable of deciding whether a pattern, which represents a feature (physical, chemical, etc.) of a specific material sample, belongs to a predetermined category. Different approaches can be found in the literature [2]: *template matching* measures the similarity between two entities such as points, curves or shapes of the same type; *statistical classification* methods choose those data features with which pattern vectors belonging to different categories occupy disjoint regions in a new feature space; in *syntactic or structural matching* a pattern is represented as composed of simple sub patterns in a hierarchical way; and, finally, *neural networks* are able to learn complex nonlinear input-output relationships using training procedures which are adapted to the data.

In template matching, the accuracy in the determination and representation of the material templates, referred as prototypes, has a direct impact on the result of the discrimination. Conventional matching procedures measure similarity by evaluating the distance between templates[2]. Simple metrics, that could be efficient in time response, could increase the misclassification rate. For this reason, a trade-off between the algorithm execution time and the classification error must be considered and optimized. In this work, the performance of the method is tested by discriminating absorbance spectra of different samples of liquids[5]such as water and sugar liquid.

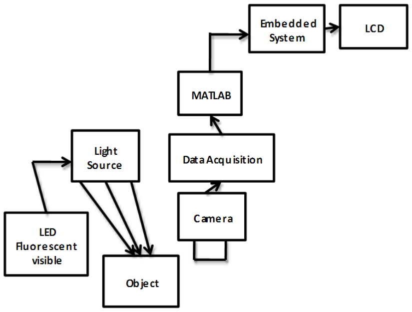

Fig. 1. Architecture Diagram

II. LINEAR INTERPOLATION

Generally, linear interpolation takes two data points, say (x_a, *ya*) and (x_b, *yb*), and the interpolant is given by:

$$y = y_a + (y_b - y_a)\,[(x - x_a)/\,(x_b - x_a)] \qquad (1)$$

At the point (x, y).

Linear interpolation is quick and easy, but it is not very precise. Another disadvantage is that the interpolant is not differentiable at the point x_k.

The following error estimate shows that linear interpolation is not very precise. Denote the function which we want to interpolate by *g*, and suppose that *x* lies between x_a and x_b and that *g* is twice continuously differentiable. Then the linear interpolation error is

$$|f(x) - g(x)| \leq c(x_b - x_a)^2 \qquad (2)$$

Where,

$$c = (1/8) \max_{y \in |xa,xb|} \left|g^{\theta}_{(y)}\right| \qquad (3)$$

In words, the error is proportional to the square of the distance between the data points. The error in some other methods, including polynomial interpolation and spline interpolation (described below), is proportional to higher powers of the distance between the data points. These methods also produce smooth interpolants.

Fig. 2. Image of Water

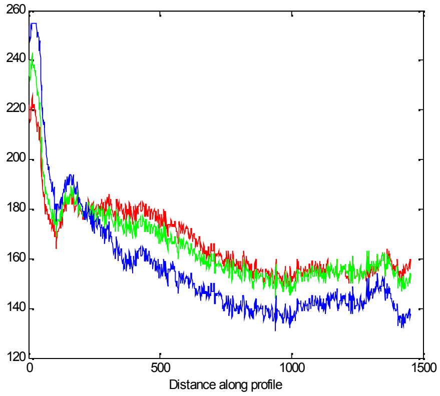

Fig. 3. Pixel Characteristics of Water

Fig. 4. Image of Sugar Liquid

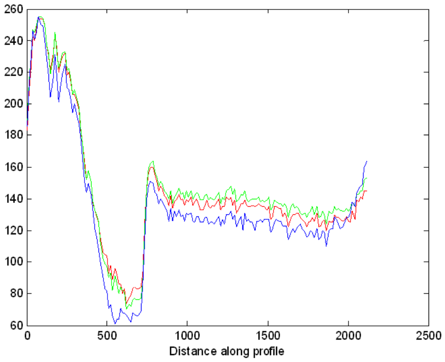

Fig. 5. Pixel Characteristics of Sugar Liquid

III. RADON TRANSFORM

Let $f(\mathbf{x}) = f(x,y)$ be a continuous function vanishing outside some large disc in the Euclidean plane $\mathbf{R}^2$. The Radon transforms, Rf

, is a function defined on the space of straight lines L in $\mathbf{R}^2$ by the line integral along each such line:

$$\text{Rf (L)} = \int_L f(x)|dx| \qquad (4)$$

concretely, any straight line L can be parameterized by

$$(x(t),y(t)) = ((t\sin\alpha + s\cos\alpha), (-t\cos\alpha) + s\sin\alpha)) \qquad (5)$$

Where s is the distance of L from the origin and α is the angle the normal vector to L makes with the x axis. It follows that the quantities (α,s) can be considered as coordinates on the space of all lines in $\mathbf{R}^2$, and the Radon transform can be expressed in these coordinates by

$$Rf(\alpha,s) = \int_{-\infty}^{\infty} f(x(t),y(t))dt \qquad (6)$$

$$= \int_{-\infty}^{\infty} f((tsin\alpha + scos\alpha),(-tcos\alpha + ssin\alpha))dt$$

More generally, in the n-dimensional Euclidean space $\mathbf{R}^n$, the Radon transform of a compactly supported continuous function f is a function Rf on the space Σ_n of all hyper planes in $\mathbf{R}^n$. It is defined by

$$Rf(\xi) = \int_{\xi} f(x)d\sigma(x) \qquad (7)$$

for $\xi \in \Sigma_n$, where the integral is taken with respect to the natural hyper surface measure, $d\sigma$ (generalizing the $|d\mathbf{x}|$ term from the 2-dimensional case). Observe that any element of Σ_n is characterized as the solution locus of an equation

$$X.\alpha = s \qquad (8)$$

Where $\alpha \in S^{n-1}$ is a unit vector and $s \in \mathbf{R}$. Thus the n-dimensional Radon transform may be rewritten as a function on $S^{n-1}\times\mathbf{R}$ via

$$\text{Rf }(\alpha,s) = \int_{X.\alpha=s} f(x)d\sigma x \qquad (9)$$

It is also possible to generalize the Radon transform still further by integrating instead over k-dimensional affine subspaces of $\mathbf{R}^n$. The X-ray transform is the most widely used special case of this construction, and is obtained by integrating over straight lines.

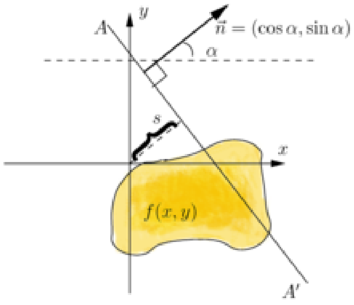

Fig. 6. Radon transform

IV. SIMULATION RESULTS

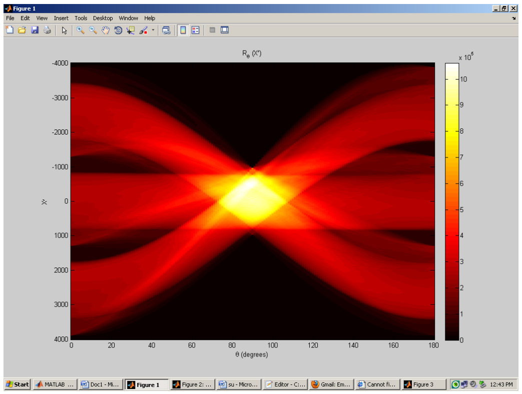

Fig. 7. Sinogram of water

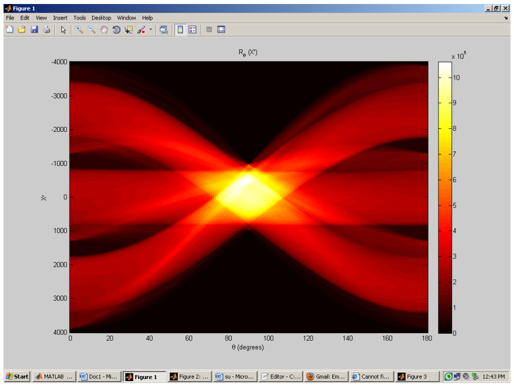

Fig. 8. Sinogram of sugar liquid

The simulation results are shown above.

Fig. 3 shows the pixel characteristics of water and Fig 5 shows the pixel characteristics of sugar liquid.Comparing both the figures there exists pixel variations.The variations are shown for the three coloured pixels R,G,B.Fig 7and Fig 8 shows the sinogram of water and sugar liquids.It is provided with the colour bar using which the variation may be identified.

VI. CONCLUSION

This work proposes and demonstrates the feasibility of a new algorithm for qualitative discrimination analysis. The proposed methodology has been named “qualitative material discrimination using radon transform” because it is based on the association of each material category to a specific figure, shape or mark and sonogram related to the absorption spectrum of the material. Furthermore, an indirect treatment of the outliers is also performed because data points outside the statistics defining the width of the marks are removed[8]. Additionally, the main advantage of the proposal relies on its fast implementation. The feasibility of the algorithm has been validated with the automatic discrimination of different liquid samples.

The classification of an unknown sample only need to perform pattern recognition operations between a reduced set of prototype images, each of them representing a material category. This procedure can be easily translated to hardware processing platforms (Embedded systems). A project of applying the strategies of Pattern Recognition[2] and Cluster Analysis to do Data Mining for interesting data sets acquired from liquid image databases may be considered. The goal of visualization, prediction, and policy making to improve the life quality and security of liquid may be pursued if the data are available.

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