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REPLY TO ATTN OF: FM84 (74-143)

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MEMORANDUM

TO: Informal Distribution

FROM: FM8/Mathematical Physics Branch

SUBJECT: Pattern Recognition Algorithm Using Temporal Data

At the present time, classification is limited almost exclusively to the use of spectral information. This memorandum presents a method for classification using spectral and temporal information.

The value of a previously classified image may be seen by means of the following example: Suppose two images are taken of a scene at different times, "then" and "now." Suppose no classification errors were made in classifying the image "then." Further, suppose no change in class occurred for any pixel between "then" and "now." Finally, suppose the images are registered perfectly; every element in each image is associated exactly with its appropriate counterpart. In this case, the second image is already classified. No additional classification effort needs to be performed. Since these three error sources are, in fact, always present, their effects should be modeled to estimate appropriate a priori probabilities for the second image.

Probability of a Signal X Belonging to Class π_i

For the discussion, assume a signal X is to be classed into one of two classes, π_1 or π_2. The generalization to any number of classes will be obvious. Suppose $f_1(X)$ and $f_2(X)$ are the probability distributions of π_1 and π_2, respectively, evaluated at X, and that N_1 and N_2 are the numbers of elements in the image in π_1 and π_2, respectively. Then, there exists $N_1 f_1(X)$ elements in π_1 with signal value of X, and similarly for π_2. This means the probability of X belonging to π_i is

$$P(\pi_i | X) = \frac{N_i f_i(X)}{N_1 f_1(X) + N_2 f_2(X)}$$

The a priori probability of π_i is

$$\alpha_i = \frac{N_i}{N_1 + N_2}$$

Hence,

$$N_i = \alpha_i (N_1 + N_2)$$

or

$$P(\pi_i | X) = \frac{\alpha_i (N_1 + N_2) f_i(X)}{\alpha_1 (N_1 + N_2) f_1(X) + \alpha_2 (N_1 + N_2) f_2(X)}$$

$$P(\pi_i | X) = \frac{\alpha_i f_i(X)}{a_1 f_1(X) + \alpha_2 f_2(X)} \qquad (1)$$

This is the probability that a signal belongs to class π_i given that the value of the signal is X.

Probability that a Pixel V Changed Class

Suppose a pixel V in the first image was a vacant lot and was correctly classified "then." However, in the time interval between the two images, a house was built on pixel V. Clearly, the probability of this happening must be considered in computing appropriate a priori probabilities for the second image. The probability of change of pixel from π_i to π_j will be denoted by $P(\pi_i \rightarrow \pi_j)(V)$. Note, the probability of change depends on π_i and π_j as well as the location V.

Assigning a value to the probability of change will require a model. Experience may be sufficient. For example, a county agricultural agent would have a knowledge of when harvest for a particular crop π_i might occur, and would assign a high probability for $P(\pi_i \rightarrow \pi_j)(V)$ at harvest time, where V was associated with the crop π_i, and π_j is the classification bare soil.

Probability of Misregistration

Denote by g(V,U) the probability of registering V in the old image with U in the new image. This means that in classifying pixel U in the new image, and attempting to use information from the old image response of pixel U, there is the probability g(V,U) that the information from pixel V will be used instead. Consequently, in calculating the a priori probability of pixel U, the effect of the surrounding pixels, weighted by their respective probabilities, must be considered.

Putting It All Together

Recall $P(\pi_j | X)$ denotes the probability of class π_j given the signal X. Suppose a pixel V had a signal response of X "then." The probability that pixel V "now" belongs to class π_i is

$$\sum_j P(\pi_j | X) \cdot P(\pi_j \rightarrow \pi_i)(V)$$

Finally, since pixel U in the new image is not necessarily registered exactly to its corresponding point in the old image, a weighted average of the above probabilities of V must be made, where the weight is the probability that U and V are registered. Hence, the probability that U in the new image is in class π_i is

$$P(U \epsilon \pi_i \text{now}) = \sum_V \{g(V,U)[\sum_j P(\pi_j | X) \cdot P(\pi_j \rightarrow \pi_i)(V)]\}$$

Notice, no assumption is made so far concerning the definition of $f_i(X)$, $P(\pi_j \rightarrow \pi_i)(V)$, or $g(V,U)$. The method is entirely general. In fact, defining $P(\pi_j \rightarrow \pi_i)(V)$ will probably require knowledge of the specific application. However, some reasonable probability distributions may be suggested for $f_i(X)$ and $g(V,U)$. For example, $f_i(X)$ may be assumed to be a discretized transformation of a normal distribution, where the mean and covariance data are defined from training sets. The distribution function for registration $g(V,U)$ may be assumed normal with expected value U. The covariance matrix may be estimated using the registration residuals of known points.

This algorithm will be coded in the near future, and will be tested using real and simulated data.

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