DECLARATION OF ERIC PEPPER

I, Eric A. Pepper, am over twenty-one (21) years of age. I have never been convicted of a felony, and I am fully competent to make this declaration. I declare the following information to be true to the best of my knowledge, information, and belief:

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3. I make this declaration based on my personal knowledge, information contained in the business records of SPIE, or confirmation with other responsible SPIE personnel with such knowledge.

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Exhibit	Reference	Date of Public Availability
A	W. B. Schaming, "Adaptive gate multifeature Bayesian statistical tracker," SPIE Vol. 359, Applications of Digital Image Processing IV (1982)	March 17, 1983

6. Exhibit A was obtained via the SPIE Digital Library, where it is maintained and distributed in the ordinary course of SPIE's business, and is a true and correct copy of the Exhibit as it existed on November 28, 2016.

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9. Attached hereto as Exhibit B is the Certificate of Copyright Registration submitted to the United States Copyright Office for SPIE Vol. 359 in which Exhibit A appears. Section 1 of the Certificate of Copyright Registration indicates the Issue Date of Volume 359 as March 17, 1983, and the Effective Date of Registration as May 6, 1983.

Pursuant to Section 1746 of Title 28 of United States Code, I declare under penalty of perjury under the laws of the United States of America that the foregoing is based on personal knowledge and information and is true and correct to the best of my knowledge and belief.

Executed on 28th day of November, 2016 at Bellingham, Washington.

By: ______________________

Eric A. Pepper

EXHIBIT A

Adaptive gate multifeature Bayesian statistical tracker

W. B. Schaming
RCA Advanced Technology Laboratories
Camden, New Jersey 08102

Abstract

A statistically based tracking algorithm is described which utilizes a powerful segmentation algorithm. Multiple features such as intensity, edge magnitude, and spatial frequency are combined to form a joint probability distribution to characterize a region containing a target and its immediate surround. These distributions are integrated over time to provide a stable estimate of the target region and background statistics. A Bayesian decision rule is implemented using these distributions to classify individual pixels as target or nontarget. An adaptive gate process is used to estimate desired changes in the tracking window size.

Introduction

This paper documents progress during the past year toward the development and demonstrations of a statistical tracking algorithm. Papers[1,2] presented in 1981 described some of the initial concepts in this development. Since that time, the statistical tracking algorithm has been expanded to incorporate (a) the simultaneous use of multiple features, (b) an adaptive gate process for control of the window size, and (c) positional dependence of the misclassification cost factor.

The tracking algorithm is based on the use of multifeature joint probability density functions for the statistical separation of targets from their background. The features currently being used are intensity, edge magnitude, and a pseudo spatial frequency feature. These features are combined to form the joint distributions which characterize a target region and its immediate surround. The distributions are integrated over time to provide a stable estimate of the target and background statistics. A Bayesian decision rule is implemented using these distributions to classify individual pixels as target or nontarget within a tracking window. An adaptive gate process is used to estimate desired changes in the tracking window size. The algorithm at present assumes manual target designation.

RCA believes this tracking process is capable of operation in all environments; insensitive to target type, signature, and orientation; applicable to a variety of sensors; and extendable to multisensor processing and readily implementable.

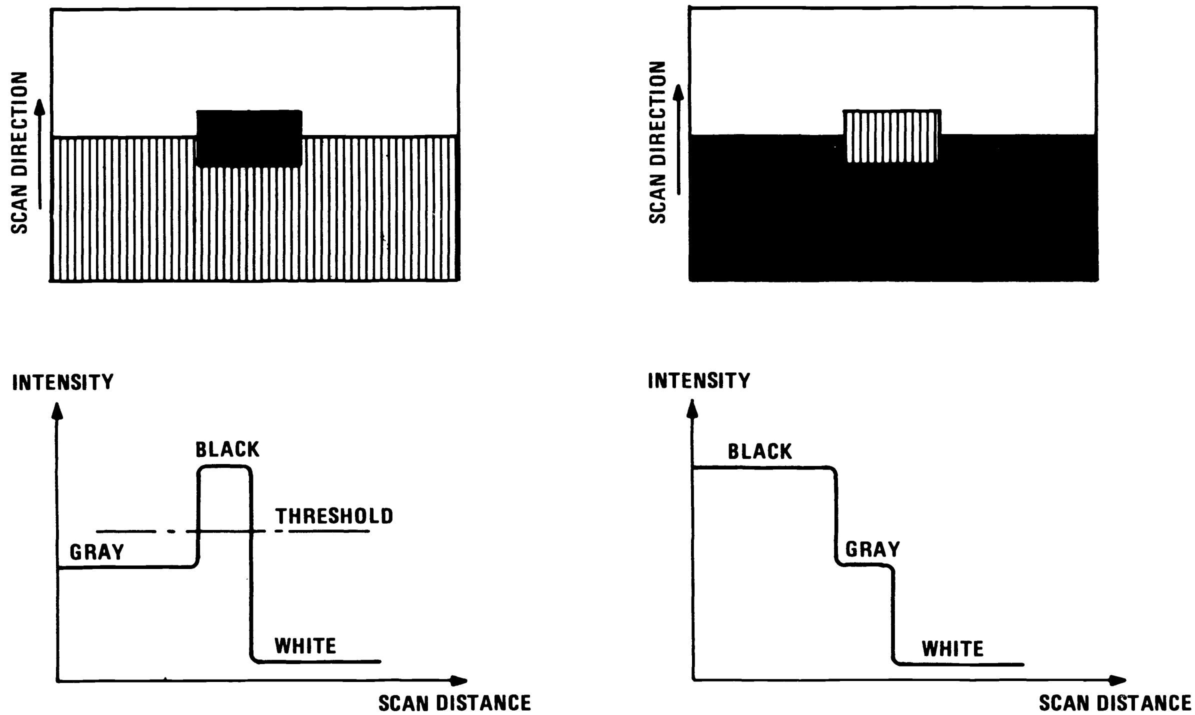
Preprocessing and A/D conversion

The video preprocessing function is an important part of any imaging sensor system, but is more critical when the sensor is an IR device which may exhibit very high dynamic range capability. In this case it is insufficient to perform a simple AGC based upon global statistics because the subsequent rescaling to reduce the dynamic range will destroy the low contrast local detail. Instead, some form of local adaptive contrast enhancement should be applied in which the gain varies with the local contrast. Lo[3] simulated and compared several such techniques.

Although necessary in a hardware implementation, this function has not been included in the simulations reported here. Ten-second image sequences were digitized from video tape via an analog video disc and an image processing system. The input to the image processing system was passed through a video processing amplifier so that the levels could be properly matched to the A/D converter.

Statistical tracking algorithm

Targets are often separated from their background by a simple thresholding scheme. Sometimes the computation of the threshold is quite sophisticated and involves looking at the statistics of the video signal. However, thresholding is inherently limited in ability as can be seen by the diagrams in Fig. 1. A simple black and white target can be readily thresholded to isolate it from its background. On the other hand a gray target cannot be thresholded without using a pair of thresholds properly placed to contain the intensity levels on the target. This dual threshold in itself is not prohibitive, but rather the problem lies in the ability to place the thresholds at the appropriate levels.



(a) THIS TARGET CAN BE EASILY THRESHOLDED

(b) THIS TARGET CANNOT BE EASILY THRESHOLDED BUT REQUIRES A PAIR OF THRESHOLDS PROPERLY PLACED.

Fig. 1. Example showing two postulated targets. One is easily segmented from the background using a single threshold. The other, however, requires two thresholds which are not easily determined. The statistical process provides a separate threshold for each intensity level.

The statistical segmentation process is a technique which provides an improved method for extracting the target from its background. Figure 2 depicts this process. Shown are two histograms, one taken from a window area of the image containing the target and the other taken from the immediate surround which represents the background. A single feature, intensity, is shown in these histograms for illustrative purposes. The shape of the distribution shown is arbitrary; there are no assumptions made about their actual shape. The segmentation process makes a separate assessment of each bin in the histogram to determine if pixels whose intensity falls in the bin are more likely to be target or background. In addition to solving the threshold selection problem, the statistical tracking algorithm provides a method to both simplify the multimode tracking concept and provide added capability.

The simplification comes about in the following way. State-of-the-art multimode trackers typically operate a contrast, edge, and correlation tracker in parallel. An executive process may be defined to determine at any given time which tracking mode is providing the most reliable estimate of target position. The statistical process, as currently defined, eliminates this mode polling process by combining the available features into multi-dimensional statistics representing target and background. Consider the use of intensity and edge magnitude as the two candidate features. In this case the statistical approach encompasses three tracking modes in an integrated single mode without the need to poll the performance of the individual processes. When intensity is the best target background separator, the algorithm operates like a contrast tracker. When edge magnitude is predominate it operates similar to an edge centroid tracker. Because the process is searching for pixels in the current frame that are statistically similar to those pixels selected as target in previous frames, the algorithm is in a sense a correlation type process as well.

The added capability comes from the fact that there are target/background conditions which are inseparable using two features independently but are readily separable using the same two features jointly. This is illustrated quite simply in Fig. 3. In this example, neither edge magnitude nor intensity can be used independently to separate the target from background because both flat distributions cover the entire variable range for both features. On the other hand, the joint distribution clearly delineates the two areas.

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