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EDITORIAL

La revista *Científica* continúa siendo un medio de difusión del conocimiento científico y tecnológico al publicar trabajos originales que contribuyen al desarrollo del conocimiento en diversas áreas de la ciencia y tecnología, así como artículos que presentan una revisión profunda sobre diversos temas de interés actual. En este número se publican artículos relacionados con la ingeniería mecánica, la ingeniería eléctrica, la electrónica y la computación.

El primer artículo presenta la detección subóptima del desplazamiento de objetos tridimensionales en donde tanto el objeto como el fondo se suponen objetos gaussianos. Al suponer estas condiciones se puede derivar un filtro quasi-óptimo basado en un modelo de señal débil con radio de fondo fluctuante a fondo no fluctuante desconocido. El sistema propuesto muestra un funcionamiento claramente superior a los sistemas convencionales.

Seguidamente se presenta una alternativa que permite establecer el costo variable por el soporte de voltaje de los generadores, donde el costo total por el soporte de voltaje se establece por un costo fijo, calculado a partir de un factor de recuperación anual del capital invertido en el generador y el costo variable propuesto. Se presenta la evaluación del sistema de prueba de 30 nodos.

El tercer artículo presenta el desarrollo de un nuevo modelo matemático para la evaluación del coeficiente de operación de una bomba de calor de Carnot que opera en tiempo finito (COPBCTF), en donde se asume que el ciclo en el que opera esta bomba de calor es internamente reversible y externamente irreversible. La ecuación resultante está conformada por los siguientes parámetros: temperatura de la fuente de baja temperatura (TB), temperatura del sumidero de alta temperatura (TA), conductancia térmica en el proceso de absorción de calor (UA)B y conductancia térmica en el proceso de rechazo de calor (UA). La ecuación desarrollada para el COPBCTF es una ecuación general ya que al aplicar las condiciones de un proceso de transferencia de calor reversible se transforma en la ecuación para el coeficiente de operación de bomba de calor de Carnot reversible (COPBCR).

Se presenta también un estudio que evalúa la cinética de difusión del boro en el acero AISI 1045 y en el acero AISI M2 durante el proceso de borurización en pasta. Esta técnica de endurecimiento superficial produce en el material la formación de dos fases características, FeB y Fe2B, y una zona de difusión en la interfase capa/sustrato. El tratamiento termoquímico se realizó a las temperaturas de 1193, 1223 y 1273 K con tiempos de 2 y 6 h para el acero 1045, y de 1223, 1253 y1273 K con los mismos tiempos de tratamiento para el acero M2 modificando los potenciales de boro que rodean la superficie de los sustratos. Se determinó la movilidad del boro en la superficie de ambos aceros, donde la influencia del potencial de boro, tiempo y temperatura del tratamiento es visible en la cinética de crecimiento de las fases presentes.

Uno de los esquemas más usados en el reconocimiento de patrones es el relativo a las memorias asociativas. En este artículo se describe una metodología simple pero efectiva para el reconocimiento de palabras impresas a partir de versiones incompletas de ellas. La metodología propuesta incorpora dos etapas principales, una de aprendizaje de palabras y otra de reconocimiento. Los espacios entre letras son detectados por medio de técnicas apropiadas de segmentación. El patrón completo compuesto de letras identificadas y espacios detectados es presentado a la memoria entrenada correspondiente, que en turno responde con la salida deseada. Se dan las condiciones formales de reconstrucción de una palabra en presencia de letras faltantes. Se dan además ejemplos numéricos y con ejemplos reales para demostrar la eficiencia de la propuesta.

El control automático es otro tema de gran importancia en el campo de la ingeniería. Con esta finalidad se presenta un esquema de control neuronal directo adaptable con uno o dos términos integrales y son propuestos para ser aplicados con plantas multivariables. El esquema de control contiene dos modelos de redes neuronales recurrentes entrenables (RNRE). La primera RNRE es un identificador de los parámetros y estimador de los estados de la planta. La segunda RNRE es un controlador *feed-back/feed-forward* con término integral. El buen desempeño del control neuronal adaptable con término integral es confirmado con un análisis del comportamiento del sistema en laso cerrado y con resultados de simulación obtenidos usando un modelo multivariable de un evaporador de simple efecto, perturbado por ruidos y afectado por pequeños retardos en sus entradas.

Finalmente se presenta una evaluación de un sistema de reconocimiento de hablantes basado en rasgos dinámicos de la señal de voz, lo que muestra que las características dinámicas de los coeficientes LPC-Cepstral (delta y doble delta cepstral) pueden ser usados para mejorar el funcionamiento de un sistema de reconocimiento de hablante, debido a que los coeficientes delta y doble delta representan la derivada con respecto al tiempo de los coeficientes LPC-Cepstral (velocidad y aceleración), lo que permite reducir la sensibilidad de los coeficientes LPC-Cepstral a variaciones del canal. Los resultados obtenidos por simulación muestran que usando estos vectores característicos, el funcionamiento del sistema mejora en comparación con el istema convencional.

Así, este número presenta contribuciones que colaborarán a incrementar el conocimiento en campos relativos a las ingenierías eléctrica, mecánica y electrónica; así como al de la informática.

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Suboptimal Detection of 3-dimensional Optical Moving Target

Victor Golikov
Olga Lebedeva

Universidad Autónoma del Carmen (UNACAR),
Av. 56, núm. 4, Col. Aviación,
Ciudad del Carmen, Camp.,
CP 24180.
MÉXICO.

Tel/Fax 9383826516

e-mail: vgolikov@pampano.unacar.mx

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1. Summary

The problem of matched-filter detection of three dimensional moving target has been considered. Both the signal and background clutter are assumed to be Gaussian processes. The proposed quasi-optimal matched filter is derived based on a weak signal model and unknown ratio of intensity of no-fluctuating background to fluctuating background. Mathematical equations for the computation of the quasi-optimal matched filter and its received characteristics have been derived. We have shown that the proposed detector exhibits performance, which is clearly superior to that of the well-known detector in case of presence of an intensive no-fluctuating background.

2. Abstract

This paper describes a suite of techniques for the autonomous detection of moving targets by processing electro-optical sensor imagery (such as visible or infrared imagery). A new algorithm is proposed for the solution of an important class of detection problems: the detection of small, barely discernible, moving objects in presence of correlated fluctuating background and constant background intensity. We assume that ratio of the correlated fluctuating background variance to constant background intensity is not known and the constant background intensity is more than its variance. A comparison of the performance of the well-known and proposed algorithms is included. Proposed algorithm shows improvement in performance over the well-known algorithm in reducing of the constant background intensity and it is suboptimal in presence of correlated fluctuating background.

Key words: Image processing, MIT, fluctuating and no fluctuating background, suboptimal detection.

3. Introduction

A research topic of interest in both, the image processing and the optical community are the improvement of the efficiency of using infrared (IR) imagery obtained from a staring mosaic IR sensor in geosynchronous orbit to realize the moving target identification (MTI). The first approach to the problem of MTI has been to look for changes between sequential frames. Rausch *et al.* have proposed the temporal differencing filter to detect changes in the imagery [1, 2]. Unfortunately, most algorithms designed to detect changes caused by moving targets also detect some changes introduced by background motion or fluctuation. Mohanty has shown that potential track trajectories of a weak point target can be assembled through exhaustive search of all possible trajectories in a given frame sequence [3]. In this approach, relatively many trajectories are estimated («tracked») in 3D dimensional image. Then, the posterior probability function is computed for each of tracked trajectories. Finally, each trajectory whose posterior probability is above a certain threshold is declared as a target. Unfortunately, any scanned image of reasonable size can create a prohibitively large number of possible trajectories to be searching, making this unattractive approach to target detection. Barniv used dynamic programming and attempted to reduce this approach to a more reasonable level through specific knowledge of potential speed windows and target shape [4]. In the works [5, 6, 7] the maximum likelihood approach is proposed. A more robust detecting technique [8] has been developed by Reed, Gagliardi, and Shao [9] for detecting weak, moving targets in background clutter using 3-D matched filtering. This method performs a moving target signature matched filtering with proper signal phasing automatically applied to «coherent» sum the target energy and reduces background noise and clutter. In these works the background is assumed to be quasi-stationary Gaussian process with known matrices. However, in case of the unknown ratio of a fluctuating-to-no fluctuating background this method does not give high efficiency.

In summary, the differencing techniques sacrifice algorithm performance significantly in case of fluctuating background, while the quasi-optimal matched filtering techniques have a large losses in case of no fluctuating background and unknown ratio of a *fluctuating-to-no fluctuating background*. Therefore, the critical problem is to find some form of quasi-optimal matched filtering that is more effective one. A technique to perform the matched filtering in case of unknown ratio of *no fluctuating-to- fluctuating background* is a main contribution of this paper. Also we intent to examine 3-D matched filters. Calculated examples are given to demonstrate an effectiveness of proposed method. The results show the ability to detect targets below the background level using the proposed processing well procedure. It is assumed that the scene background is a sum of colored stationary random field, no fluctuating background and target that occupies about 4x4 pixels while moving with a known velocity direction and a speed of one pixel per frame.

4. Algorithm description

A sequence of T (M x N) digital images is given as:

$$I(m,n,t) = \{I(m,n,t\,|\,1\le m\le M, 1\le n\le N, 1\le t\le T)\} \qquad (1)$$

So, the problem is to detect any target in the image volume. The target initial position and velocity are unknown. It is assumed that the target satisfies a multipoint-source model, and the image pixel with coordinates (m,n) can be modeled by observations vector $\boldsymbol{y}_{m,n}$,

where:

$\boldsymbol{y}_{m,n} = \boldsymbol{s}_{m,n} + q(\boldsymbol{n}_{m,n} + \alpha \boldsymbol{c}_{m,n})$: under the target present hypothesis H_1 ,
$\boldsymbol{y}_{m,n} = \boldsymbol{n}_{m,n} + \boldsymbol{c}_{m,n}$: under the target absent hypothesis H_0 ,
$\boldsymbol{s}_{m,n}$: Vector of a unknown fluctuating signal;
$\boldsymbol{n}_{m,n}$: Vector of a colored Gaussian background;
$\boldsymbol{c}_{m,n}$: Vector of a no fluctuating background;
q : Signal-to-background ratio;
α : No fluctuating-to-fluctuating background ratio (for received signals).

For independent vectors $\boldsymbol{y}_{m,n}$ the optimum Neyman-Pearson detector results [9]:

$$\sum_{m=1}^{M}\sum_{n=1}^{N} \mathbf{y}^{T}_{m,n}\mathbf{Q}\mathbf{y}_{m,n} \underset{>}{\le} \eta \qquad (2)$$

where:
$\boldsymbol{Q} = (\boldsymbol{R}_n + \beta \boldsymbol{R}_c)^{-1}$.
$\boldsymbol{R}_n$ and $\boldsymbol{R}_c$: fluctuating and no fluctuating background covariance matrices correspondently;
η : threshold;
$(R_c)_{p,k} = 1$;
β : No fluctuating-to-fluctuating background ratio (for processing matrix $\boldsymbol{Q}$).

The decision threshold η is set to yield the desired value of the false alarm probability P_{FA}. At an unknown position of the target in the image we use a M_1-by-N_1 windows which sizes are matched with the sizes of the target. The quasi-optimum Neyman-Pearson detector (2) may be rewritten in the case of independent vectors $\boldsymbol{y}_{m,n}$:

$$\mathbf{z}^{T}\mathbf{Q}\mathbf{z} \underset{>}{\le} \eta_1 \qquad (3)$$

where:

$$\mathbf{z} = \sum_{m=1}^{M_1}\sum_{n=1}^{N_1} \mathbf{y}_{m,n} \qquad (4)$$

At the unknown ratio *no fluctuating-to-fluctuating background* let's create the algorithm completely canceling no fluctuating background assuming that β>>1. In this case we can calculate a limit:

$$\begin{aligned} \boldsymbol{P} = \lim_{\beta\to\infty}\boldsymbol{Q} &= \{1/\beta\,(\boldsymbol{R}_n)^{-1}[(1/\beta\,)\boldsymbol{I} + \boldsymbol{R}_c(\boldsymbol{R}_n)^{-1}]^{-1}\} \\ &= (\boldsymbol{R}_n)^{-1} \lim_{\beta\to\infty}(1/\beta\,)\boldsymbol{W}^{-1} \end{aligned} \qquad (5)$$

where : $\boldsymbol{I}$: unit matrix, and $\boldsymbol{W} = (1/\beta)\boldsymbol{I} + \boldsymbol{R}_c(\boldsymbol{R}_n)^{-1}$.

The matrix $\boldsymbol{W}^{-1}$ has the following determinant and algebraic adjuncts [10]:

$$\Delta = \frac{1}{\beta^{T-1}}\sum_{k=1}^{T}\sum_{l=1}^{T}(R_n)^{-1}_{kl} + \frac{1}{\beta^{T}}$$

$$A_{kk} = \frac{1}{\beta^{T-2}}\Big(\sum_{i=1}^{T}\sum_{j=1}^{T}(R_n)^{-1}_{ij} - \sum_{j=1}^{T}(R_n)^{-1}_{kj}\Big) + \frac{1}{\beta^{T-1}}$$

$$A_{kl} = -\frac{1}{\beta^{T-2}}\sum_{j=1}^{T}(R_n)^{-1}_{kj}$$

Let's calculate a limit:

$$\lim_{\beta\to\infty}(1/\beta)(W^{-1})_{kk} = \lim_{\beta\to\infty}(1/\beta)\frac{A_{kk}}{\Delta} =$$

$$1-\frac{\sum_{j=1}^{T}(R_n)_{kj}^{-1}}{\sum_{i=1}^{T}\sum_{j=1}^{T}(R_n)_{ij}^{-1}}$$

$$\lim_{\beta\to\infty}(1/\beta)(W^{-1})_{kl}=-\frac{\sum_{j=1}^{T}(R_n)_{lj}^{-1}}{\sum_{i=1}^{T}\sum_{j=1}^{T}(R_n)_{ij}^{-1}}$$

Then $\mathbf{P}=(\mathbf{R}_n)^{-1}(\mathbf{I}-\mathbf{U})$,

where $$\mathrm{U}_{\mathrm{kl}}=\frac{\sum_{j=1}^{T}(R_n)_{lj}^{-1}}{\sum_{i=1}^{T}\sum_{j=1}^{T}(R_n)_{ij}^{-1}}$$

Finally, we obtain the expression for matrix **P** elements:

$$\mathrm{P}_{\mathrm{kl}}=(\mathrm{R}_{\mathrm{n}}^{-1})_{\mathrm{kl}}-\frac{\sum_{i=1}^{T}(R_n^{-1})_{ki}\sum_{j=1}^{T}(R_n^{-1})_{lj}}{\sum_{i=1}^{T}\sum_{j=1}^{T}(R_n^{-1})_{ij}} \qquad (6)$$

Finally, we obtain the test:

$$\mathbf{z}^{T}\mathbf{P}\mathbf{z}\ \underset{\geq}{\overset{\leq}{}}\ \eta_1 \qquad (7)$$

The matrix **P** always satisfies to the condition

$$\sum_{l=1}^{T}P_{kl}=0 \qquad (8)$$

for all *k*.

This condition corresponds to full indemnification of no fluctuating background. Matrix **P** always will be singular and at least one of its eigenvalues is equal to zero. For example, for diagonal matrix **P** (in case of white noise and no fluctuating background) we have:

$$P_{kl}=\left[\begin{array}{ll}(T-1)/\sigma^2T & \text{for } k=l\,,\\[2ex] -1/\sigma^2T & \text{for } k\neq l\,,\end{array}\right. \qquad (9)$$

where σ^2 is a variation of noise. One of eigenvalues of such matrix is equal to zero, and the others are defined by the formula $\lambda_m = 1/\sigma^2$. In case of exponential covariance matrix of background and no-fluctuating background we can write:

$$P_{kl}=\left[\begin{array}{ll}
1/\sigma^2-\dfrac{1-r}{2\sigma^2(T-1)} & \text{for } k=l=1;\ k=l=T;\\[2ex]
-r/\sigma^2-\dfrac{1-r}{\sigma^2(T-1)} & \text{for } k-l=\pm1;\\[2ex]
-\dfrac{1-r}{2\sigma^2(T-1)} & \text{for } k=0,\ l=T;\ k=T,\ l=0;\\[2ex]
-\dfrac{1-r}{\sigma^2(T-1)} & \text{for } k-l=\pm3\ldots\pm(T-1);\\[2ex]
2/\sigma^2-\dfrac{2(1-r)}{\sigma^2(T-1)} & \text{for } k=l=2\ldots T-1;
\end{array}\right.$$

Further we investigate influence of distinction between matrixes **Q** and **P** on performance of detection in case of absence and presence of no fluctuating background.

5. Performance comparison

The criteria for the evaluation are oriented toward the objective of MIT. The traditional measure of the performance of a simple algorithm for use in this area is a measure so called the *background suppression factor (BSF)* [11] that is defined in such a way:

$$BSF=\frac{\sqrt{\overline{x}^{2}}}{\sqrt{\overline{e}^{2}}} \qquad (10)$$

where :
x : intensity of the pixels before processing,
e : intensity of the pixels after processing.
$\bar{x}$, $\bar{e}$ arithmetic means.

BSF gives a measure of the level of background suppression and has been included for comparison purposes, but notice that perfect background suppression may be obtained by setting the entire image to 0. This is not a very useful procedure for identifying a target so an additional more complex criterion which is called Neyman-Pearson one is usually used.

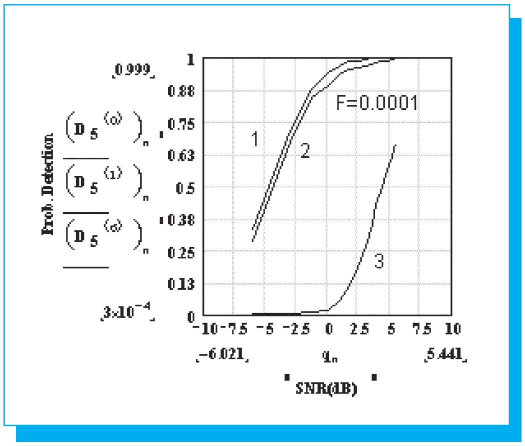

Fig. 1. ROC curves for $\mu = 0.1$, $\gamma = 0.01$ and $\alpha^2 = 10$; 1) optimal algorithm, 2) proposed algorithm, 3) well-known algorithm for $\beta = 0$.

Following this target detection criterion the probability of detection is calculated at the fixed probability of a false alarm. Corresponding curves name receiver operating characteristics (ROC).

We test the well-known optimal test (3) and the proposed test (7) for comparison purposes. Below, it will be demonstrated that in case of the unknown *no-fluctuating-to-fluctuating background ratio* α the loss of the optimal test can reach a significant size. Let's notice also, that frequently in case of unknown parameter of received signal α in the optimal test the value β is accepted equal 0.

The detection probability D and false alarm F can be obtained for tests (3) and (7) from such the expression [12,13]:

D (or F) =

$$\sum_{j=1}^{H} \frac{1}{(k-1)!} \frac{d^{k-1}}{d\lambda_j^{k-1}} \left\{ \lambda_j^{k-1} \exp\left(\frac{-\eta_1}{\lambda_j}\right) \prod_{\substack{m=1 \\ m\neq j}}^{H} \left(1-\frac{\lambda_m}{\lambda_j}\right)^{-p} \right\} \qquad (11)$$

where :

$H \le T$: number of difference positive eigenvalues λ_m for matrix

$$\Lambda = \left[\begin{array}{ll} \mathbf{PR}_b & \text{for an absent signal,} \\ \mathbf{P}(\mathbf{R}_b + q^2\mathbf{R}_z) & \text{for a present signal,} \end{array}\right.$$

$\mathbf{R}_b = \mathbf{R}_n + \alpha^2\mathbf{R}_c$: background covariance matrix of $\boldsymbol{z}$,

$\mathbf{R}_z$: signal covariance matrix of z ,

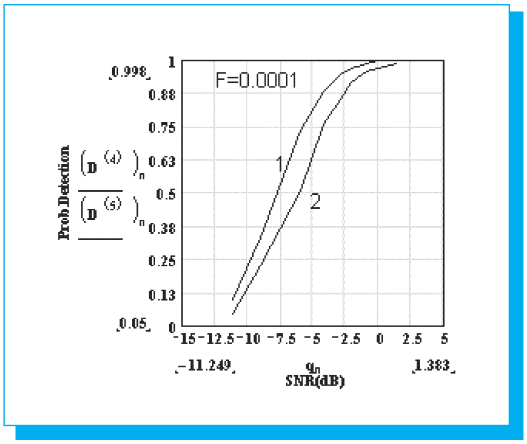

Fig. 2. ROC curves for $\mu = 2$, $\gamma = 0.01$ and $\alpha^2 = 1$; 1) optimal algorithm, 2) proposed algorithm.

k,p : eigenvalues multiplicity of λ_j, λ_m correspondently,

q^2 : signal-to-clutter and noise ratio of z.

Let's obtain the *ROC* for following covariance matrix of z :

$$R_z(i,k) = [\exp(-\gamma|i-k|)](1-|i-k|/4) \qquad (12)$$

Using a characteristic equation Det$(\boldsymbol{\Lambda} - \lambda\mathbf{I}) = 0$, we can obtain the eigenvalues. For example, in a case of white noise background and $\gamma \ll 1$ considered above matrix $\boldsymbol{\Lambda}$ has such the eigenvalues:

$$\left.\begin{array}{l} \lambda_1 = \lambda_2 = \ldots = \lambda_{T-1} = 1, \\ \lambda_T = 0 \end{array}\right] \quad \text{for an absent signal} \qquad (13)$$

$$\left.\begin{array}{l} \lambda_1 = \lambda_3 = \ldots = \lambda_{T-1} = 1, \\ \lambda_2 = 1 + q^2 \sum_{i=1}^{T}\sum_{k=1}^{T} P_{kl}(1-|i-k|/4) \\ \lambda_T = 0. \end{array}\right] \quad \text{for a present signal} \qquad (14)$$

Substituting (13) (for F) and (14) (for D) in (11) we can write the equations for detection probability D and false alarm probability F:

$$F = \frac{1}{(T-2)!} \frac{d^{T-2}}{d\lambda_1^{T-2}} \{\lambda_1^{T-2} \exp(-\frac{\eta_1}{\lambda_1})\} \qquad (15)$$

$$D=$$

$$\frac{1}{(T-3)!}\frac{d^{T-3}}{d\lambda_1^{T-3}}\{\frac{\lambda_1^{T-2}}{\lambda_1-\lambda_2}\exp(-\frac{\eta_1}{\lambda_1})\}+\frac{\lambda_2^{T-2}}{(\lambda_2-\lambda_1)^{T-2}}\exp(-\frac{\eta_1}{\lambda_2}) \quad (16)$$

We have assumed that form of a spatial window and form of the moving target are identical with such the sizes $M_1=N_1=4$ and a number of processed images $T=7$. Also, we assume that the target velocity is equal 1 pixel per second. The covariance matrix elements in the case of background fluctuations is assume to have such a form:

$$R_n(i,k) = \sigma^2[\exp(-\mu|i\text{-}k|)] \quad (17)$$

In case of $\alpha^2=10$ the receiver operating characteristics for optimal (and known α) test (3) and proposed test (unknown α) (7) are illustrated in Figure 1, where *signal/noise relation* is SNR (dB) = 10 $\log_{10} q^2$, and the ratio is $\alpha^2=10$.

The presented in the Figs. 1,2 curves show that the losses of well-known algorithm is equal to 7.5 dB for D=0.5. It is possible to explain these losses by the background suppression factor. In case of well-known test BSF = 5 but for proposed algorithms gives BSF = 55 and for optimal test BSF = 57. The loss of the proposed test in relation to optimal test is less than 1 dB that confirms it effectiveness.

Figure 2 illustrates the case when the ratio $\alpha^2=1$ showing that proposed test has loss about 1 dB for D = 0.5.

6. Conclusion

This work presents spatial and temporal processing algorithm for detection of small moving objects in image sequences that also contain fluctuating and no fluctuating background. Using the spatial-temporal model for the targets and background we have developed a 3-ary hypothesis testing procedure, derived the corresponding decision rule in case of partially unknown background covariance matrix and presented its performances analyzing ROC curves. This analysis has confirmed the effectiveness of the derived algorithm.

7. References

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