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An approach to the thermo vision image preprocessing

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A new approach to primary thermal image processing method has been proposed in this paper. The object of the preprocessing is the image generated by the first generation thermal image camera that uses scanning by vertical array of detectors. This type of image contains a certain number of artificial lines, known in the references as 'false lines'. These inserted lines do not contain any useful information, and may cause some additional problems in the process of target detection and tracking. The proposed method is based on the analysis of the image auto-correlation function. This function is used as indicator of false lines existing, FIR (Finite Impulse Response) filters are used for image preprocessing in order to decrease the influence of false lines, and as a quality of the algorithm the smoothness of the auto-correlation function has been considered. The drawback of the method is decreasing of the image contrast. This contrast is smaller as the order of the filter is higher. High contrast is required in order to detect and track the targets efficiently. These two contradictory effects call for a compromise choosing the filter order. The results of the proposed algorithm have been illustrated through the processing of the real thermo vision image.

Key words: **thermovision, image processing, image creation, image quality, target detection, target tracking.**

Introduction

ONE of the most important thermo vision camera applications is aerial target detection and tracking. This paper considers the first generation of thermo vision cameras that use vertical arrays of 120 detectors with horizontal scanning for odd and even lines separately [1]. It makes 240 lines altogether (Fig.1). However, this number of lines is not enough for standard TV resolution. For that reason some special cameras contain circuit boards with the basic target to generate additional lines until full resolution. The procedure of generating these lines, so called false lines, is not available in the references. The false lines appearance

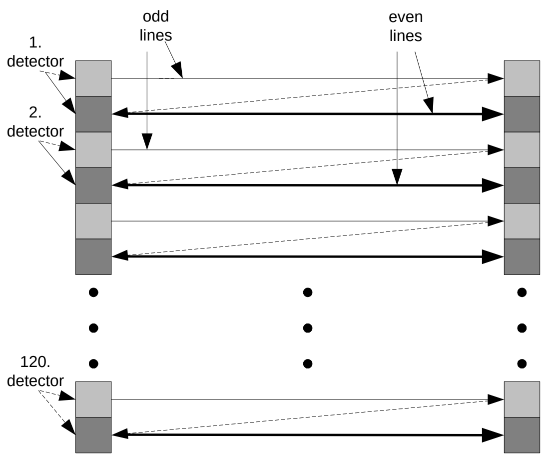

Figure 1. Line scanning principle for the first generation of thermo vision cameras

may be detected in two ways. One is visual perception. The structure of such image seems to be with sharp lines. The viewer's eye has an impression that the successive horizontal lines do not belong to the same frame. The feel of smoothness is missing. The other possibility to detect the false lines existing is to analyze the auto-correlation function of the image [2], [7].

Presentation of the proposed method

The definition of auto-correlation function of zero-mean discrete stationary stochastic process is:

$$R_x(i) = E\{x(i+k)x(k)\} \tag{1}$$

where E denotes mathematical expectation. Since the thermo vision signal is two-dimensional, and as the probability density function of the image pixels is not known, the logical procedure to estimate the auto-correlation function of the pixels belonging to the k-th column is as follows

$$\hat{R}_k(i) = \frac{1}{N_l - i}\sum_{l=1}^{N_l - i} x(l+i,k)x(l,k) \ ; \ i = 0,1,2,... \tag{2}$$

where $x(l,k)$ presents the intensity of the pixel located in l-th line and k-th column. N_l presents the number of image lines. To generate the function that describes the whole image, it is necessary to calculate the mean value of the auto-correlation functions for all the columns:

$$\hat{R}\ (i) = \frac{1}{N_k}\sum_{k=1}^{N_k}\hat{R}_k(i) \ ; \ i = 0,1,2,... \tag{3}$$

where N_k represents the number of image columns. Fig.2a

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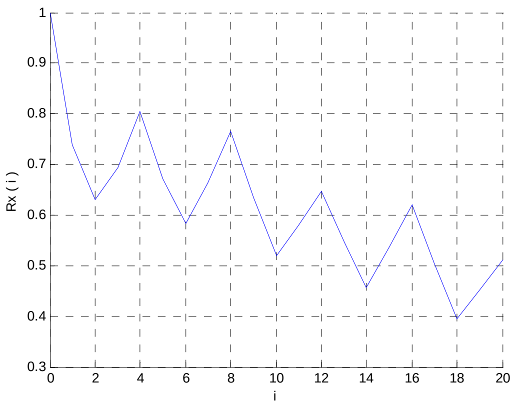
shows a thermo vision frame using the wide field of camera view mode. The frame contains the target at a distance of about 5 km. Fig.2b represents the auto correlation function according to relation (3). The auto correlation function is normalized so that $\max_i \hat{R}\ (i)=1$.

The influence of the “false” lines contained in the image may be seen through the local maxima and minima in the auto correlation function. On the other hand, since almost 95% of the image is made by the background and the target takes less than 5% of the image structure, it is expected for the auto correlation function to have a form of smooth monotonously decreased function. In other words, it is natural to expect the auto correlation function very similar to the one corresponding to the white process.

a)



b)

Figure 2. a) Thermo vision image recorded with a wide field of view camera, b) Auto correlation function of image 2a.

The periodical components in the auto-correlation function with period of 4 lines are caused by false lines at even positions. Basic idea presented in this paper, is to define the algorithm for decreasing the influence of the false lines, and on the other hand, to take care about the contrast of the target. The smoothness of the auto correlation function will be considered as the measure of the false lines influence. The algorithm will be based on the FIR (Finite Impulse Response) filters design, as it is described in the following chapter.

Finite impulse response filter design

Having in mind that the main goal of the thermal image preprocessing is the visual smoothness of the image along the vertical axis, the FIR filter application is proposed as a natural solution. Assuming that $x(i,k)$ and $y(i,k)$ denote gray level of a pixel located in the i -th line and κ-th column in the original thermo vision image, and processed image, respectively, the output of the filter $y(i,k)$ may be assumed as:

$$y(i,k)=a_0x(i,k)+a_1x(i-1,k)+\cdots a_nx(i-n,k) \quad (4)$$

where n is the order of filter and $a_0, a_1,..., a_n$ are unknown filter coefficients. By using the delay operator z^{-1}, the last relation may be written in the following compact form [5], [6]

$$y(i,k)=A\left(z^{-1}\right)x(i,k) \quad (5)$$

where polynomial A is at n - th order of variable z^{-1}:

$$A\left(z^{-1}\right)=\sum_{i=0}^{n} a_i z^{-i} \quad (6)$$

Respecting the nature of the signals x and y, some restrictions must be applied to the unknown coefficients:

$$a_0>0, a_1>0,..., a_n>0, \sum_{i=0}^{n} a_i = 1 \quad (7)$$

Assuming that the filter order n is unknown, the choice of this order must be done in such a way to make a compromise between two opposite requests. Firstly, as the main target is to make the auto correlation function of the image $\{y\}$ as smooth as possible, the order *n* of the filter should be higher. On the other hand, the high filter order will damage the information of the target position in the image, decreasing the contrast of the filter output. In order to express the smoothness (the monotonousness) of the auto correlation function, the following criterion was introduced:

$$J=\sum_{p=1}^{\infty}\left(\hat{R}_y(p)-\hat{R}_y(p-1)\right)h\left(\hat{R}_y(p)-\hat{R}_y(p-1)\right) \quad (8)$$

where function $h(x)$ is a unit step function:

$$h(x)=\begin{cases}1\ ; & x\geq 0\\ 0\ ; & x\langle 0\end{cases}$$

The definition of the criterion function J provides easy detection of the non-monotonous intervals of the auto correlation function $\hat{R}(.)$. Criterion function *J* is a function of the filter order n and coefficients $a_0,..., a_n$. In order to minimize the criterion, the Nelder-Mead numerical algorithm was used [3]. The procedure iterative with respect to the filter order *n*. Fig.3 presents the optimal value of criteria *J* depending on the assumed filter order *n*. The presented results were obtained by applying the proposed method for the image given in Fig.2a.

Based on Fig.3 it may be conclude that criterion *J* decreases rapidly with the increase of the filter order. On the other hand, higher filter orders produce decrease of image variance, and this variance is directly connected to the possibility to detect the target in the image. In order to compute the contrast in the area of the target, the image variance within the window located around the target position was defined [8]:

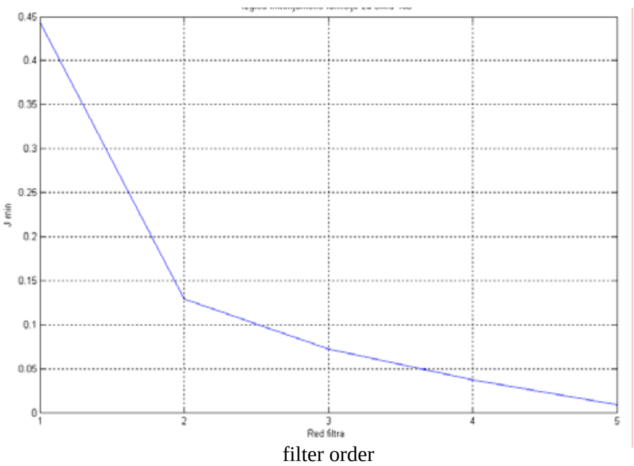


Figure 3. Optimal value of criteria J (8) versus the filter order n

$$\hat{\sigma}^2 = \frac{1}{4\Delta_l\Delta_k}\sum_{i=-\Delta_l}^{\Delta_l}\sum_{k=-\Delta_k}^{\Delta_k}\left(y(i_c-i,k_c-k)-\hat{m}(i_c,k_c)\right)^2 \quad (9)$$

where $2\Delta_l$ and $2\Delta_k$ represent the dimensions of the rectangular window, and $\hat{m}(i_c,k_c)$ presents estimated target position:

$$\hat{m}(i_c,k_c) = \frac{1}{4\Delta_l\Delta_k}\sum_{i=-\Delta_l}^{\Delta_l}\sum_{k=-\Delta_k}^{\Delta_k} y(i_c-i,k_c-k) \quad (10)$$

Fig.4 presents the dependence of the variance (9) on the filter order.

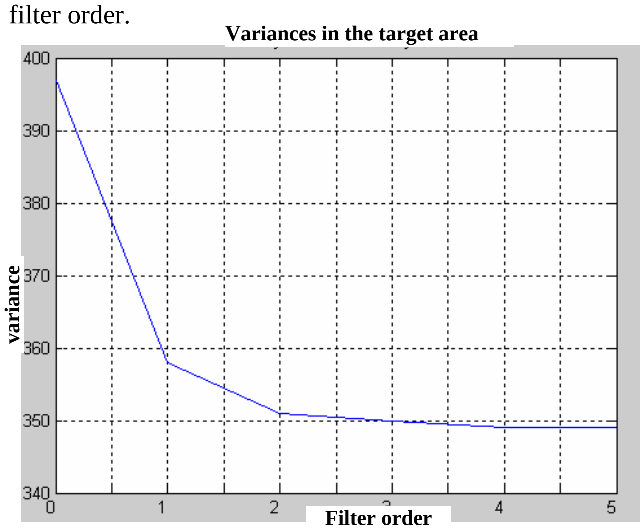


Figure 4. Image variance in the area of target versus filter order

The simulation results based on the proposed method are presented in the following chapter.

Simulation results

As illustrations of the proposed methodology, the real thermo vision image presented at Fig.2a was used. It was obtained by the wide field of view camera (WFOV). Fig.5 shows the auto correlation functions of the images obtained after the filtering of the original image (Fig.2a). The order of the filters was changed from 1 up to 5, and five different auto-correlation functions may be seen in the figure. Nelder-Mead algorithm has been applied in order to minimize the criterion (8) and for the fifth order of the filter, the following polynomial *A* has been obtained as the result:

$$A(z) = 0.1825 + 0.0752z^{-1} + 0.2437z^{-2} + 0.2014z^{-3} + 0.1042z^{-4} + 0.1930z^{-5} \quad (11)$$

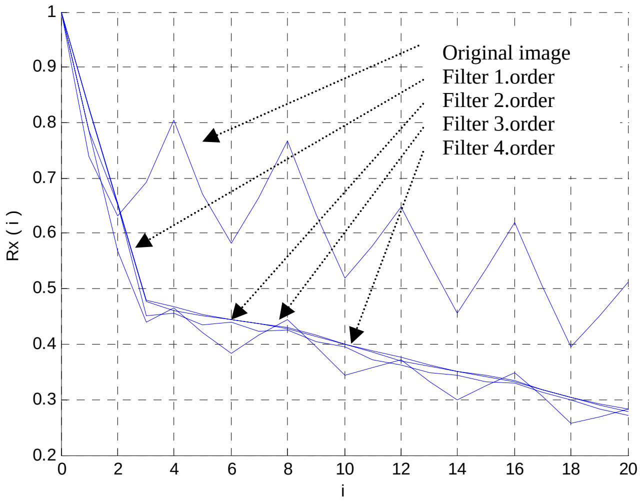


Figure 5. Normalized cross correlation function for original and filtered images by different filter orders

The filtered image, when the filter order was five, is presented in Fig.6.

Figure 6. Processed thermal image

In order to illustrate the effect of filtering on the contrast change in the area of target, this area before and after filtering was presented. Fig.7a presents this area in the original image, while Figures 7b, 7c and 7d represent the area of target after applying the filter of first, third and fifth order, respectively.

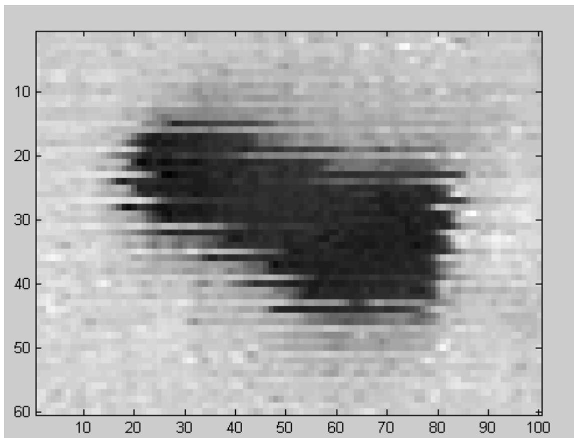


Figure 7a. Original thermal image in the area of the target

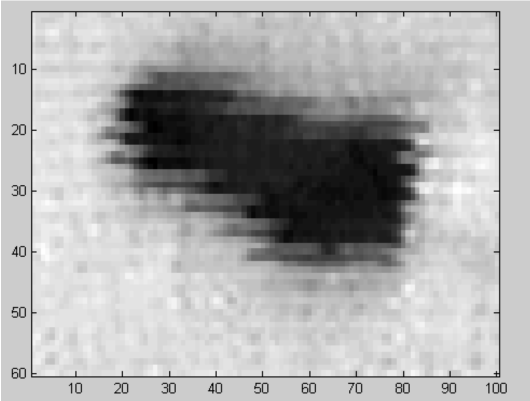


Figure 7b. Image after filtering by filter of 1.order

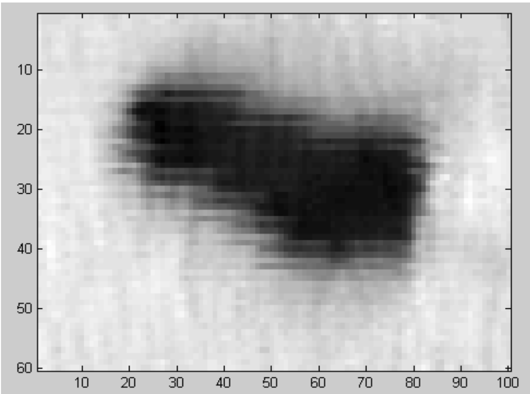


Figure 7c. Image after filtering by filter of 3.order

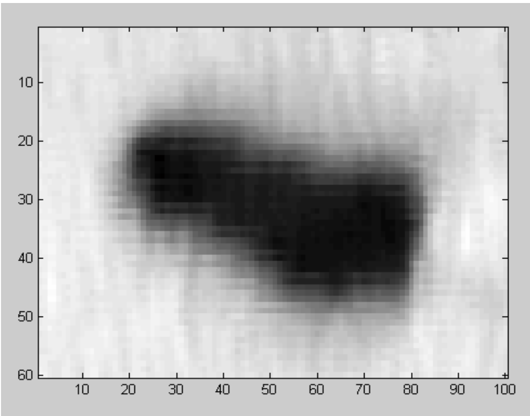


Figure 7d. Image after filtering by filter of 5.order

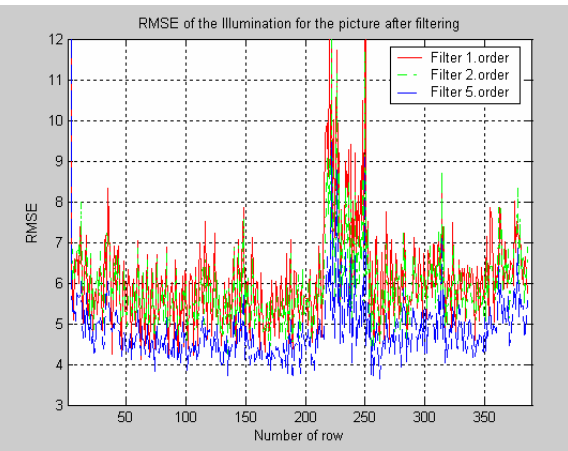


Figure 8a.

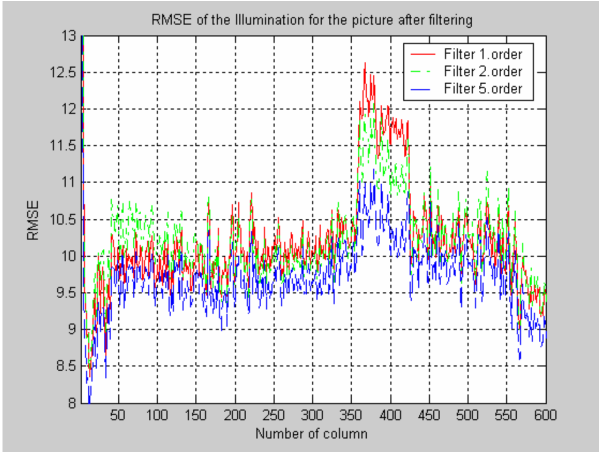


Figure 8b.

According to the relation (9) the image variance in the target window were calculated and the following results obtained. The variance for the original image was 397 and after the filter application this variance is decreased slowly. Following the fifth order filter application its value was 349. In order to illustrate that this variance (contrast) is still enough for target detection, the variance in the areas where the target does not exist was calculated, obtaining values less than 310.

Conclusion

The paper considers the problem of ”false lines” appearance contained in the thermo vision images obtained by the first generation thermo vision cameras. The presence of these lines degrades the efficiency of the algorithms for detection and moving targets tracking. The auto correlation function of the image pixels is used to quantify the effect of the “false lines”. A new algorithm, based on finite impulse response filters, is proposed in the paper. The coefficients of the filter are chosen in a way to minimize the properly defined criterion function. The criterion function is designed to estimate the “smoothness” of the auto correlation function of the filtered image. As the “smoothness” is stronger, the performance is weaker. Therefore, the filtered image should be natural, smooth, without extra artificial lines in the image texture. On the other hand, the high order filters decrease the image contrast in the area of target location. Simulation results have shown that this decrease is not crucial and the detection process may be done properly after the filtering process. Finally, the proposed algorithm may be used as a useful preprocessing method for the thermo vision images.

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Jedan primer predobrade termovizijskih slika

U radu je predložen metod za primarnu obradu slika nastalih termovizijskom kamerom prve generacije, linijskim skeniranjem scene vertikalnim nizom detektora. Ovakva slika sadrži određeni broj veštačkih linija koje se u literaturi nazivaju «false lines». Ceo postupak ovakvog formiranja slike se naziva «interlacing». Ove umetnute, lažne, linije ne doprinose informativnosti slike a, u velikoj meri mogu narušiti efikasnost metoda za otkrivanje i praćenje ciljeva pomoću termovizije. Metoda predložena u ovom radu koristi autokorelacionu funkciju kao meru uticaja lažnih linija na kvalitet slike, dok se filtri sa konačnim impulsnim odzivom koriste kao alat za eliminisanje ovog uticaja. Nepovoljna posledica ovakve predobrade jeste smanjenje kontrasta slike u oblasti cilja, što u velikoj meri smanjuje verovatnoću njegove detekcije. Odgovarajući kompromis se mora naći kroz podesno izabran kriterijum za minimizaciju oštećenja kontrasta. Primenjivost predložene procedure je ilustrovana kroz primere predobrade na dva realna termovizijska kadra.

Ključne reči: **termovizija, obrada slike, formiranje slike, kvalitet slike, otkrivanje cilja, praćenje cilja.**

Один пример предварительной обработки термовизионных изображений

В этой работе предложен метод для предварительной обработки изображений, сделаных термовизионной камерой первой генерации, линейным сканированием сцены вертикальной матрицей детекторов. Такое изображение содержит определенное число искусственых линий, которые в литературе называются Чфалсе линесЧ. Комплектный поступок такого формирования изображения называется винтерлацингг. Эти вставленные, ложные, линии не способствуют информационному содержанию изображения, а в большой степени могут испортить эффективность метода для обнаружения и сопровождения целей при помощи термовизии. Предложенный метод в этой работе пользуется автокорреляционной функцией как мерой влияния ложных линий на качество изображения, пока фильтры с конечной импульсной идентификацией пользуются в роли прибора для устранения этого влияния. Неблагоприятным последствием такой обработки является уменьшение контраста изображения в области цели, что в большой степени уменьшивает вероятность его детектирования. Соответствующий компромисс нужно найти через пригодно выбран критерий для минимизации повреждения контраста. Применяемость предложенной процедуры представлена примерами предварительной обработки на двух реальных термовизионных кадрах.

Ключевые слова: термовизия, обработка изображения, формирование изображения, качество изображения, обнаружение цели, сопровождение цели.

Un exemple du traitement primaire des images de thermovision

Ce travail propose une méthode du traitement primaire des images produites par les thermovision caméra de la première génération qui utilise scanning de ligne d'une série vérticale du détecteur.Une telle image contient un certain nombre de lignes artificielles appelées « false lines ».Le procédé complet de cette formation de l'image est appelé »interlacing ». Ces lignes, fausses et intercalées, ne contribuent pas à l'informativité de l'image et, en grande partie, peuvent nuire à l'efficacité des méthodes qui sont employées à détecter et suivre les buts à l'aide de thermovision. La méthode proposée utilise la fonction autocorrelationnelle comme mesure d'influence des fausses lignes sur la qualité de l'image, alors que les filtres avec la réponse d'impulsion finale sont utilisés comme outils pour éliminer cette influence. La conséquence défavorable de ce traitement primaire est la diminution du contrast de l'image dans le domaine du but, ce qui diminue considérablement la probabilité de sa détection.Il faut trouver un compromis convenable au moyen d'un critère bien choisi pour minimiser les dégas du contrast. Les possibilités d'application de procédé proposé sont illustrées par les exemples du traitement primaire sur deux cadres réels de thermovision.

Mots clés: **thermovision, traitement d'image, formation d'image, qualité d'image, détection de but, poursuite de but.**