Motion Detection in Thermal Images Sequence Using Wigner Distributions

Sn. Pleshkova, Al.Bekyarski

***Abstract*—**Motion detection is wide spread action in video systems to discover objects or people in images. A number of methods and algorithms have been proposed for estimating 2D motion detection in images. Some of these methods may be classified as matching methods, other as methods of differentials, spectral methods like Fourier methods, Wigner distribution etc. Matching and differential methods are simple to use, but not always work, because of noise presence usually in the images and because the variation in the gray-scale intensities from one image to the other. The Fourier methods are very popular and are based on phase spectrums subtraction of the images from two neighbor frames in images sequences. This leads to a set of two algebraic equations with two unknowns. The Fourier methods work well for motion estimation of single object, but for the case of multiple objects these methods cannot distinguish the motion of one object from that of the other. All of these methods are possible to modify and apply as methods and algorithms of motion detection in thermo visual systems. In this article is developed the method and algorithm for motion detection in thermal images carried out the analysis of two dimensional Wigner distributions. The proposed method is tested in simulations and in real working thermal image system to detect motion and tracking people in sequences of thermal images and the results of the experiments are shown in comparison with the similar methods.

***Keywords*—**Motion Detection, Thermo Vision Systems, Thermal Image Sequence, Motion Detection, Wigner Distributions

I. Introduction

THERMO vision is a technique for capturing the temperature distribution of the points of objects and people [1]. This distribution is presented as pseudo visual images using the relationship between temperature of each point and the color assigned to these values. The main advantages of using thermal images are the possibility to “seen” the objects and people in the darkness and in the night. The applications of thermo visual systems are quite wide in: military or police systems, security or surveillance systems, industrial inspection systems, medical systems, robots, etc. In the area of security and surveillance thermo visual systems motion detection is very important operation using to detect people or objects movements in area of surveillance system observation and applying this operation is realized also the objects and people tracking [2]. The idea of motion detection is proposed for visible images [3] and a lot of methods and algorithms are proposed, most important of which are: matching methods, methods of differentials, spectral methods like Fourier methods, Wigner distribution etc. All of these methods can be applied also in thermo visual systems for motion detection with some modifications typical for thermal images. The choice of a concrete method of motion detection in a real working thermo visual system can be made analyzing the advantages and disadvantages of the well known motion detection methods for visible images. After preparing this precise analysis in this article is chosen to develop a method and algorithm for motion detection in thermal images carried out the analysis of two dimensional Wigner distributions.

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II. Thermo Vision Images Motion Detection Method Based on Wigner Distributions

The application of Wigner distributions is wide spread in signal processing, image processing, etc.[4] One of the application of two dimensional Wigner distributions is motion detection in visible images[5]. Analyzing these methods is possible to decide whether or not is suitable to apply Wigner distributions also for motion detection in thermal images. A brief description of two dimensional Wigner distributions theory is presented first to explain the main principles of motion detection, processing thermal images with two dimensional Wigner distributions. The Wigner distribution [6] was introduced first as a representation of a signal in time and frequency variables. Subsequently, Ville [7] derived for the signals the same distribution that Wigner proposed several years ago. There exists also for images the 2D Pseudo Wigner Distribution (PWD) given by [8]:

$$PWD(n_1,n_2,\theta_1,\theta_2)=\sum_{k=-N_2+1}^{N_2-1}\sum_{l=-N_1+1}^{N_1-1}h_{N_2N_1}(k,l)*$$
$$\sum_{r=-M_2+1}^{M_2-1}\sum_{s=-M_1+1}^{M_1-1}g_{M_2M_1}(r,s)z(n_1+r+k,n_2+s+l)*$$

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$$z^*(n_1+r-k,n_2+s-l)e^{-j2(k\theta_1+l\theta_2)} \quad (1)$$

where

z and z^* is input thermal image and it complex conjugation;

M_1, M_2, N_1, N_2 - discrete spatial-averaging variables;

$h_{N_2N_1}(k,l)$ - spatial-frequency averaging window;

$g_{M_2M_1}(r,s)$ - spatial averaging window;

$n_1, n_2, \theta_1, \theta_2$ - discrete spatial variables:

$$\begin{aligned}\theta_1 &= 2\pi f / N_1\\ \theta_2 &= 2\pi f / N_2\end{aligned} \quad (2)$$

The 2D Pseudo Wigner Distribution (PWD) for described with equation (1) is applied for static thermal images. It can be modify, for dynamic thermal images or thermal image sequences containing usually moving objects, as a 6D function PWD_i, for the current i frame in thermal images sequence, defined by:

$$\begin{aligned}&PWD_i(x,y,t,w_x,w_y,w_t) =\\ &\sum_t\sum_x\sum_y R_i(x,y,t,\alpha,\beta,\tau) *\\ &* \exp[-j(\alpha w_x+\beta w_y+\tau w_t)]\end{aligned} \quad (3)$$

where

$$\begin{aligned}&R_i(x,y,t,\alpha,\beta,\tau) = z_i(x+\alpha,y+\beta,t+\tau) *\\ &* z_i^*(x-\alpha,y-\beta,t-\tau)\end{aligned} \quad (4)$$

z and z^* represent current i input frame in thermal images sequence and it complex conjugation;

x, y, α, β - correspond to $n_1, n_2, \theta_1, \theta_2$ - discrete spatial variables in equation (1) for the static thermal images.

In the case, where in a thermal image sequences (a time-varying thermal image) in the current i frame $z_i(x,y,t)$, exist an uniformly translation at some constant velocity with horizontal and vertical v_x, v_y components, the PWD of this thermal image is:

$$\begin{aligned}&PWD_i(x,y,t,w_x,w_y,w_t) = \delta(v_x w_x + v_y w_y + w_t)\\ &PWD_i(x-v_x t, y-v_y t, w_x, w_y)\end{aligned} \quad (5)$$

It is possible to define from (5), that in case of a linearly translation with velocity v_x, v_y in thermal image sequence (usually when there are the objects or people in area of thermal camera observation), the values of PWD_i are everywhere zero except in the plane defined by

$$\{(x,y,t,w_x,w_y,w_t) : v_x w_x + v_y w_y + w_t = 0\} \quad (6)$$

Therefore, it can be mentioned, that for a pixel with position *(x,y)* in current time *t* of the current *i* thermal image frame, each local spatially, temporary and frequency (STF) spectrum of the PWD_i is zero everywhere except on the plane defined by (6). From this can be concluded, that estimating the velocity from a given (STF) spectrum is equivalent of motion detection in thermal images sequence applying method of optical flow calculation.

The general approach for optical flow calculation in thermal images sequence is based on assumption that the intensity structures of local time-varying thermal image regions are approximately constant under motion for at least a short duration. This means, that changes in thermal images intensity are due only to translation of the local image intensity and not due to changes in lighting, reflectance, etc. According to this assumption, the total derivative with respect to time of the thermal image intensity function should be zero at each position in the image and at every time. For the intensity function of a current i thermal image frame $z_i(x,y,t)$ is possible to claim that intensity remain constant if it is satisfy the following condition:

$$z_i(x,y,t) = z_i(x+\delta x, y+\delta y, t+\delta t) \quad (7)$$

where

$\delta x, \delta y$ define the displacement of the local thermal image region at position (x, y) after a little time interval δt.

Equation (7) can be represented as an appropriate Taylor series:

$$v_x\frac{\partial z_i(x,y,t)}{\partial t} + v_y\frac{\partial z_i(x,y,t)}{\partial t} + \frac{\partial z_i(x,y,t)}{\partial t} = 0 \quad (8)$$

Therefore, it is proposed here in this article to use equation (6) of PWD transformation or (11) of FFT for motion detection in thermal images sequences with a procedure for estimating the slope of the motion plane found in the appropriate spectrums.

III. Algorithm for Thermo Vision Images Motion Detection Based on Wigner Distributions

The slope of motion can be determined using different methods. There are many possibilities to find this plane and their slope. In this article is proposed to develop an algorithm for slope of motion finding using Hough transform. The main advantages of Hough transform in this case is the ability to discard cross-terms that can be introduced by the PWD transform, using it for motion detection purpose. It is known that a line can be characterized in the Hough plane, as well as a line and also a plane. This is the used in this article as feature for determine the velocity of motion detected objects or people in thermal images sequences applying Hough transform to the spatially, temporary and frequency (STF) spectrum. The main steps of the proposed algorithm for thermo vision images motion detection based on Wigner distributions are presented in Fig. 1.

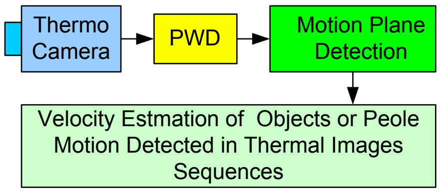


Fig.1. The main steps of the proposed algorithm for motion detection in thermo vision images sequences based on Wigner distributions

Thermal images are captured from **Thermo Camera**. The sequences of thermal images are treated to calculate 2D Pseudo Wigner Distribution – **PWD.** The information from **PWD** block is entered in the block preparing **Motion Plane Detection** applying Hough transform to the 2D Pseudo Wigner Distribution of the thermal images sequences. The results from Hough transform are used in the last block for **Velocity Estimation** of objects or people detected in thermal images sequences.

The importance of the block **Motion Plane Detection** for the processed thermal images sequences is the reason to present them more precise in Fig. 2. The Hough transform **HT** is prepared in parallel form to a number of **Frames 1 to n** of the 2D Pseudo Wigner Distribution of the thermal images sequences. Then a **Local maximum** of each of all HT of frames 1 to n is calculated, which is information of the position of local existence of motion line in each frame of thermal images sequences. In the next step is determined the **Sum of all local maximums**, assuming that every straight line found in one frame is parallel to the others. This means that every line of the HT spectrum has the same angle θ.The information provided by the angle θ of one of the peaks would be sufficient to estimate **Velocity Direction** and **Velocity Magnitude** of the moving objects in thermal images sequences. To improve the precision of moving detection in in thermal images sequences is proposed to use the redundant information of all 1 to n frames by applying the Hough transform HT to the summation of all local maximums, when calculating **Velocity Direction** and **Velocity Magnitude**. This allows discarding the existence of erroneous peaks from sum of all local maximums. This possibility is depicted in Fig. 2 as **(HT)** in parentheses in the blocks **Velocity Direction** and **Velocity Magnitude.**

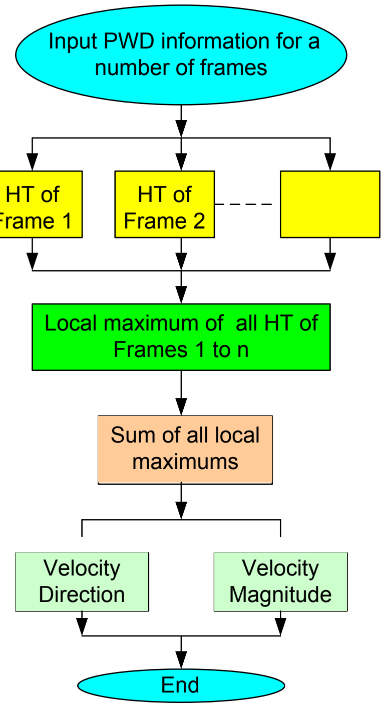
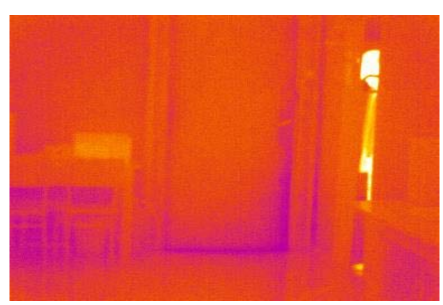


Fig.2. Motion Plane Detection and velocity determination for thermal images sequences

IV. Results and Conclusion

The proposed algorithm for thermo vision images motion detection based on Pseudo Wigner Distributions (PWD) is examined with a lot of test thermal images sequences. For brevity here in this article are presented only some parts of input (Fig. 3) and outputs (Fig. 4.) sequence of frames from a whole used in one of the experiments test thermal images sequence. It can be seen from Fig. 4, that the arrows are an indication of right calculate direction of moving person analyzing motion in two adjacent input frames of thermal images shown in Fig. 3. This indicates proper operation of the developed algorithm for thermo vision images motion detection based on Pseudo Wigner Distributions (PWD). All experiments are carried out with test thermal images sequences from a real working thermal image camera EasIR-9 [9].



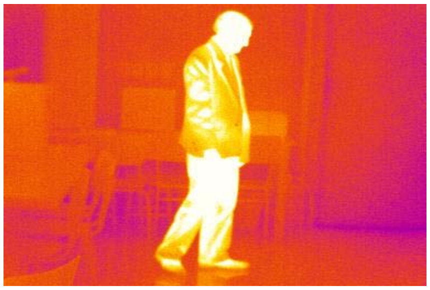


Fig.3. Three adjacent input frames
E9IRCAP 1, 2 and 3 from a test thermal images sequence

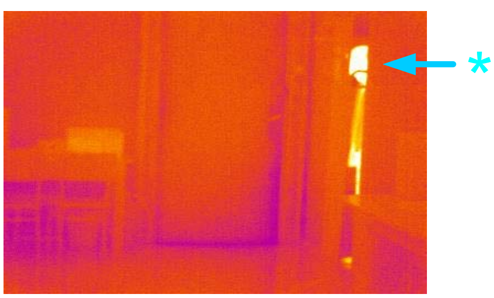


Fig.4.The same three adjacent frames of thermal images as outputs results from motion detection (shown with arrows) in a test thermal images sequence

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