New Algorithm to Detect Moving Target in an Image with Variable and Complex Background Using Wavelet Transform

Farid Jafarian and Raheleh Kafieh

***Abstract*—In this paper, a new algorithm to detect a moving target (foreground moving target) in an image with variable and complex background is presented. It should be mentioned that background in this paper is an image containing moving objects. In this method, first the edges of all objects in the image are extracted using Canny filter and GVF active contour then the target is detected using wavelet transform. The boundary of target is extracted using a new boundary detection method. As a result, the background is removed and the target is extracted. To detect the type of motion (mode of the motion) and also to intellectualize the algorithm the neural network is used. Finally the algorithm detects the type of motions. Multiplicity and diversity of complexities in the background of the images which the algorithm is applied on them, variability of the background, using Wavelet Transform to detect the desired target, proper using of GVF Active Contour, presenting and applying a new method for boundary detection and, generally the novelty and ability of our algorithm in detection of target in many different images, and also new application of all stages of this algorithm , are all reasons that discriminate our algorithm from all the methods presented in the same area.**

***Index Terms*—Boundary detection, background removal, canny filter, GVF, motion detection, wavelet transform.**

I. Introduction

Today Motion Detection is considered as one of the most important capabilities of vision systems and used in several fields including robotics, aerospace industries, military applications, developed security systems, and all systems related to intelligent vision. As a result, finding solutions for this problem is considered as a valid step forward. Recently, in most methods for Motion Detection either the background are generally removed from capture images or Ratio Images is taken as a base for motion detection.[1] Entropy is another method used for solving this problem [2], [3]. Although the base of all these methods are the same, but different methods are applied nevertheless they contain limitations and defects. There are also, several human visual system developed for detection of human. Operating based on human characteristics such as body shape and symmetry of legs and Statistical models [4], [5] and [6] that of course, these methods limited to human images [7]-[13]. The most common methods and systems of all those mentioned are presented in [14]-[20]. The shortcomings and limitations existed in all papers, ever offered in this area, made the authors of this paper to solve this problem and offering a new method. In this paper, first the characteristics and features of the images that our algorithm applied on them are mentioned. Then the ways of target detection, foreground removal, and also target motion explanations are discussed applying this method. That should be mentioned that the software Matlab is used in all stages in order to run this algorithm. In section II the image capturing method is presented. In section III applied method to background elimination is presented. In sections IV and V wavelet transform 1D and 2D is presented respectively. In section VI the type of target motion is determined. Finally in section VII conclusions is presented.

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Farid Jafarian was with Department of Electrical Engineering, Sepahan Isfahan Institute of Science and Technology, Isfahan, Iran. He is now with the Department of Electronics and Communications Engineering, University of Birjand, Birjand, Iran. (e-mail: farid.jafarian@birjand.ac.ir).

Raheleh Kafieh is with the Department of Biomedical Engineering, Isfahan University of Medical Science, Isfahan, Iran. (e-mail: address: r_kafieh@resident.mui.ac.ir).

II. Image Capturing

The image capturing method is based on the analysis of images having varieties and complexities that can cause errors in the algorithms and motion detection systems when they have not ability to detect the target among such complexities. The performance of these systems is limited and undeveloped. It should be emphasized that none of such complexities would cause occurrence of errors or limitations in our algorithm. Our proposed algorithm can detect the target despite all the complexities existing in the mentioned images. This ability is one of the strength points and advantages of our paper over the other papers presented in the same area. Some of the complexities and feature of the images are listed below:

1) Images are taken from different landscapes having different backgrounds.
2) The place of target in the images is variable.
3) There are some shapes with different dimensions, colors, shapes and characteristics in different places of the background. also this objects have variable place it means that for example in the first sequence (first image or first scene) there is a vase in the right corner of the background and in the next (second) scene there is a vase in the left corner of the background or in the background there is a moving object like a big oscillating pendulum.
4) The objects existing in the background have often harsh and dark colors to create a kind of complexity in target detection. (there are also some light colors in the

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background)

5) Images that in the background of them there are the drastic changes of frequency in order to create some disturbance in target detection. Example 3 in Fig. 5 is one of these kinds of images that have a netting fence along with harsh light in the background. This fence along with harsh light of the sun would cause errors in target detection of the algorithms.
6) There are images taken with the camera away and closer to the scene.
7) There are images with turbid background that causes error even in target detection of human eyes (example 6 Fig. 5)
8) There are some images disrupted by noise, crystallization and fading.
9) There are some images taken by various cameras with different resolutions and even different technologies such as CCD and CMOS.

III. Background Removal

As mentioned earlier, in this paper background is an image containing moving objects. The purpose of background removal or background elimination is to separate the target (foreground target) from the rest part of image. In the first stage of algorithm, the following stages are presented in the first step of the algorithm to remove the background.

A. First Stage of Algorithm

One of the most appropriate active contours called Gradient Vector Flow (GVF) is used to find the external edges of all the objects existing in the image. GVF, wasn't of course, capable of giving the desired result by itself, this matter is illustrated in the Fig. 2 Part (b). To achieve the desired result, first the edges are extracted by Canny filter then GVF is applied to the image in order to create a contour around where the energy of profile would change. In the Fig. 2 Part (c) an example of algorithm performance at this stage is illustrated.

B. The Second Stage of Algorithm

At this stage the objects are specified distinctly so that viewer can identify each object and the target as well. But the important matter is that the algorithm would be capable of discriminating the target in image. Since the intellectuality and automation of the algorithm is one of the purposes of designing this algorithm so the algorithm should detect the location of the target automatically so that other components and objects of the image would be removed. The fundamental question here is how one can identify where the target is located? (Is in the right, left, center or in somewhere else?)

The main idea of using the following method is based on the this principle that one thing would tell us or would give us the position of a target point (position of a target pixel) of the body like hands, legs, ears, head and even the position of a point somewhere in the dress and other features like these. Based on the question raised and after the assessments done, Wavelet Transform is selected to find the solution.

IV. Discrete Wavelet Transform

Two primary concepts in wavelet theory are the multi-resolution analysis and the orthogonal decomposition. Based on wavelet theory [21], any signal from the vector space of square function, $L^2(R)$, can be decomposed into the sum of its projection on a subspace V_j and W_j which orthonormal basis of the subspace V_j is represented by $\left\{\varphi_j(n-k)=2^{-j/2}\,\varphi\left(2^{-j}n-k\right)\right\}_{k\in z}$, the indexes j and k are denoted to as "scale" and "position" respectively, $\varphi(n)$ is known as *scale function* and on the subspaces W_j, j=0,1,...,J-1. The subspaces W_j are produced by translating in time and scaling is represented by $\left\{\psi_j(n-k)=2^{-j/2}\,\psi\left(2^{j}n-k\right)\right\}_{k\in z}$ a function $\psi(n)$ is known as *wavelets mother.*

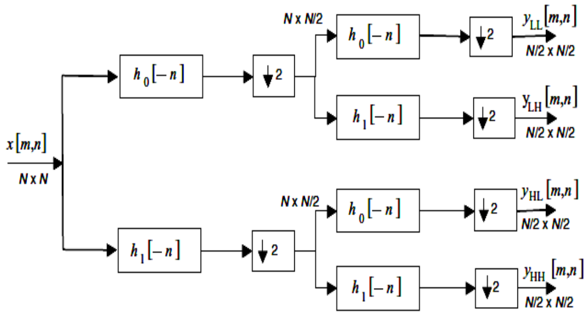

Fig. 1. Forward one-level 2D DWT

The DWT of a signal consists of two series expansions, one corresponding to the approximation and the other to the details of the sequence [3]. The formal definition of DWT of an N-point sequence x[n], $0\le n\le N-1$ is given by, [22]: where

$$DWT\{f(t)\}=W_\phi(j_0,k)+W_\psi(j,k) \tag{1}$$

$$W_\phi(j_0,k)=\frac{1}{\sqrt{N}}\sum_{n=0}^{N-1}x[n]\,\phi_{j_0,k}[n] \tag{2}$$

$$W_\psi(j,k)=\frac{1}{\sqrt{N}}\sum_{n=0}^{N-1}x[n]\,\psi_{j,k}[n],\qquad j\ge j_0 \tag{3}$$

In which the functions $\phi_{j_0,k}[n]$ are called scaling functions, $\psi_{j,k}[n]$ are called dyadic wavelets:

$$\phi_{j,k}[n]=2^{j/2}\phi[2^j n-k],\quad -\infty<j,k<\infty\quad j,k\in Z \tag{4}$$

$$\psi_{j,k}[n]=2^{j/2}\psi[2^j n-k],\quad -\infty<j,k<\infty\quad j,k\in Z \tag{5}$$

The sequence x[n], $0\le n\le N-1$ can be recovered from the DWT coefficients W_ϕ and W_ψ as given by

$$x[n]=\frac{1}{\sqrt{N}}\sum_k W_\phi(j_0,k)\,\phi_{j0,k}[n]+\frac{1}{\sqrt{N}}\sum_{j=j_0}^{\infty}\sum_k W_\psi(j,k)\,\psi_{j,k}[n] \tag{6}$$

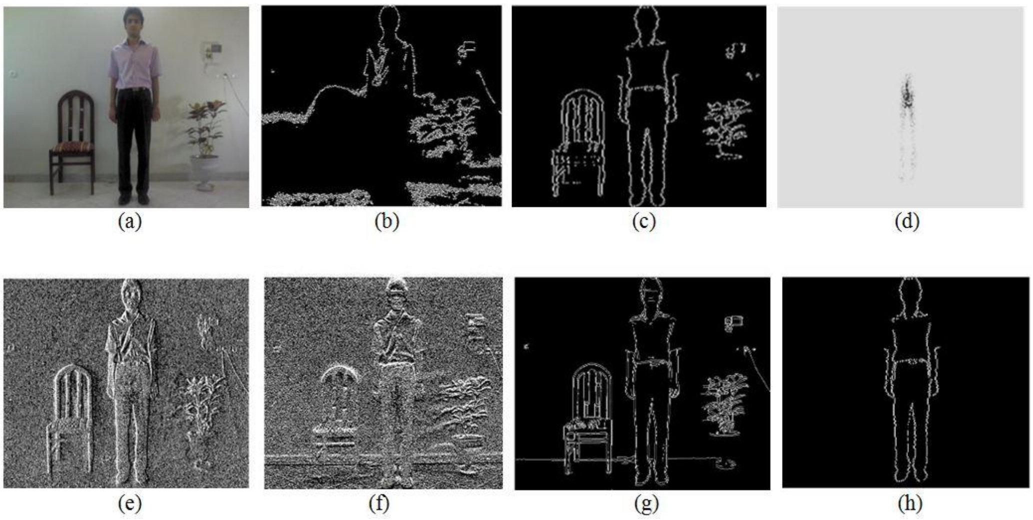

Fig . 2. (a) Original image, (b)Applying GVF on original image, (c)The edges are extracted by applying Canny filter and GVF, (d) Output of DWT2, the cA1, (e and f) outputs of DWT2, cH1 and cV1, (g)Reinforcing the edges, (h) The extracted target

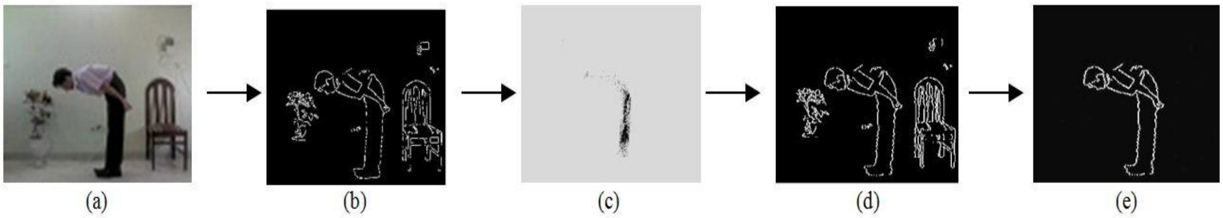

Fig. 3. a) Original image input of the algorithm b)After the first stage of the algorithm: applying Canny and GVF c) After the second stage of thealgorithm: wavelet 2D is applied on input image to determine the location of target. d): After the third stage of the algorithm: to achieve the external edges lost as the result of Canny application and to reinforce the edges e) The fourth stage of the algorithm: target extracting or background removal

The scale parameter in the second summation of (6) has an infinite number of terms. But in practice the upper limit for the scale parameter is usually fixed at some value say, J . The starting scale value j_0 *i*s usually set to zero and corresponds to the original signal. Thus, the DWT coefficients for x[n], $0 \le n \le N-1$ are computed for $j=0,1,...,J-1$; $k=0,1,...,2^j-1$. Also, N is typically a power of 2, of the form $N=2^J$. If $h_0[m]$ and $h_1[m]$ denot lowpass and highpass filters respectively. We have:

$$\phi[2^j n-k]=\sum_m h_0[m]\sqrt{2}\,\phi[2(2^j n-k)-m] \qquad (7)$$

In (7), let *l* = *m* + 2*k*. Then, (7) can be rewritten as

$$\phi[2^j n-k]=\sum_l h_0[l-2k]\sqrt{2}\,\phi[2^{j+1}n-1] \qquad (8)$$

In (7), { $h_0[m]$ } are used as the weights in the linear combination. Similarly, the wavelet function at scale j can be written in terms of the wavelet functions at scale $j+1$ using another set of weights { $h_1[m]$ } as

$$\psi[2^j n-k]=\sum_l h_1[l-2k]\sqrt{2}\,\psi[2^{j+1}n-1] \qquad (9)$$

In (7) through (9), the factor $\sqrt{2}$ is the normalization factor it is necessary that all scaling functions and wavelets have unit energy.

Replacing (8) into (2), we can express the scaling coefficients of the DWT of the input sequence at scale j in terms of the scaling coefficients at scale $j+1$ as

$$\begin{aligned} W_\phi(j,k) &= \frac{1}{\sqrt{N}}\sum_{n=0}^{N-1} x[n]\,\phi[2^j n-k] \\ &= \frac{1}{\sqrt{N}}\sum_{n=0}^{N-1} x[n]\sum_l h_0[l-2k]\sqrt{2}\phi[2^{j+1}n-1] \\ &= \sum_l h_0[l-2k]\left\{\frac{1}{\sqrt{N}}\sum_{n=0}^{N-1} x[n]\sqrt{2}\,\phi[2^{j+1}n-1]\right\} \end{aligned} \qquad (10)$$

We have

$$\frac{1}{\sqrt{N}}\sum_{n=0}^{N-1} x[n]\sqrt{2}\,\phi[2^{j+1}n-1]=W\phi(j+1,l) \qquad (11)$$

Therfore we have,

$$W_\phi(j,k)=\sum_l h_0[l-2k]\,W_\phi(j+1,l) \qquad (12)$$

By a similar reasoning, we can write the wavelet or detail coefficients of the DWT of the input sequence at scale j in terms of those at scale $j+1$ as

$$W_\psi(j,k)=\sum_l h_1[l-2k]\,W_\psi(j+1,l) \qquad (13)$$

V. Wavelet Transform 2D

To implementing the 2D DWT of an image we perform the 1D DWT in a column after row of the image, [22]. Assume the image of size $N \times N$ pixels, we first filter it row by row by the filter $h_0[m]$ and $h_1[m]$, and keep every other sample at the filter outputs. This gives a set of two DWT coefficients each of size $N \times N/2$. Next, we filter the DWT coefficients of the filter again along each column by the same two filters and subsampled by 2 to output two other sets of DWT coefficients of each size $N/2 \times N/2$.Finally, the DWT coefficients are filtered along the columns by the same two filters and subsampled to give two other sets of DWT coefficients of each size $N/2 \times N/2$. We thus have one level of DWT of the image in question. Fig.1 shows a one-level 2D DWT of an image of size $N \times N$ pixels. The four different DWT coefficients are determined as $y_{LL_1}[m,n]$, $y_{HL_1}[m,n]$, $y_{LH_1}[m,n]$ and $y_{HH_1}[m,n]$. The suffix 'LL' stands for the output of the filters in both dimensions, 'HL' For the output of along the rows first and then of along the column, 'LH' for the output of first and then of , and finally 'HH' stands for the outputs of along both dimensions. The suffix '1' refers to the level number. In order to implement this step, a command corresponding to Wavelet Transform 2D in the software MATLAB is used, to run this stage. This command is called DWT2 with the following format:

[CA1, cH1, cV1, cD1] = dwt2 (x, 'wname'), In which the inputs are (x): that is the original image and (wname): the wavelet name that is optional. The outputs are as follow:

cA1: approximation coefficients matrix is (LL) section of 2D wavelet transform *cH1*: details coefficients horizontal or (LH) section of 2D wavelet transform, *cV1*: details coefficients vertical (HL) section of 2D wavelet transform *cD1*: diagonal details coefficient (HH) section of 2D wavelet transform. Applying a 2D wavelet transform and extracting of approximation coefficients (LL) from the original image. An image (cA1) is achieved that is the problem solution. An example of algorithm performance this stage is illustrated in the Fig .2 Part (d). Moreover there are some examples of determining the location of target using this method, presented in the Fig. 5. The second image of these figures represents cA1.

Dynamic dimension of the original image should, of course, be located in a proper proportion that has a close relation with the type of selected wavelet. The detection of proper proportion is done by the algorithm (algorithm is responsible for decision about this) and determined according to the dynamic features and characteristics of image that should be analyzed. For example for Fig. 2 Part (d), the Haar wavelet (db1) existing in the software MATLAB is used.

A. The Third Stage of Algorithm

The following method is applied to achieve the external edges lost as the result of Canny application and to reinforce the edges particularly when the target dress and also the background are white and so it is hard to discriminate between them. Here, again the wavelet is used to display the differences existing in the image. So we propose following method:

In this case, the outputs cH1 and cV1 from command DWT2 is used. For example, the body parts of the target and even the clothes are somehow distinct from the adjacent areas.

This matter is well represented in Fig. 2 Part (e and f) even the clothes of the target are distinct from adjacent areas. That should be mentioned that the appropriate selection of the wavelet type would have a significant effect on the performance results. Now it is possible to achieve the more precise edges or to achieve acceptable results by transforming the image resulted from wavelet transform into small parts and calculating the mutual correlations of them and creating a threshold for the correlations. It is also possible to apply Canny filter on the output cH1, cV1. The second method is used in our paper. (That should be mentioned that these operations are done to reduce the algorithm error) an example of algorithm performance is shown in Fig. 2 Part (g).

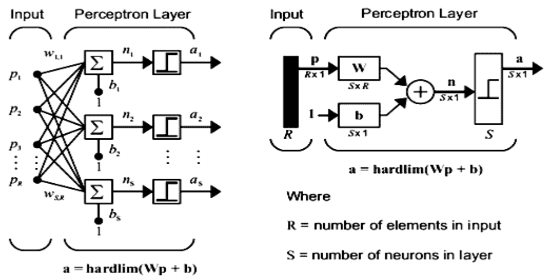

Fig. 4. Structure of Perceptron neural network

B. The Fourth Dtage of the Algorithm

Now, the edges are well extracted and reinforced, and more importantly the location of the point or points of the target position is detected, the target boundaries should be extracted from the image. The commands and methods such as bwtraceboundary common in the software Matlab and some command provided by the Mathwork company would not meet our needs since sometimes the attempt is to properly extract all edges, but the image is so complicated that some points (pixel dependent on the target) that remain latent and may discharge more than 50 pixels not understandable for the commands mentioned above. For example, as bwtraceboundary command of the software Matlab constantly asks us for zero moving direction, and the worst of all it can not define more than 8 breaking points, we would not meet our needs using this command. Contour-trace is one of the other commands unable to help us for the limitations mentioned above.

As a result, we present a new method. In this method, even if there are several breakpoints at the external edges (borders or boundaries) of the target, we don't face any difficulty finding the other edges. In programming of this sub-algorithm, there is some kind of decision-making and intellectual capability as the performance basis since there are some points of the target specified. The location of these points is used to find the correct boundary points. The parameters of this sub-algorithm including the number of breaking points are adjustable without any limitation. For example the number of breakpoint is adjustable and has no limit. The performance of the sub-algorithm is in this way that first some boundary points of the target are selected as starting points considering the location of the target already marked.

Then the points around the starting points are carefully checked and the closest boundary point to the specified points find and compared to the previous points and save as a boundary point if it's being on the border is ensured. At this stage the desired target with its location are identified and removed from the background. You can see an example of the extracted target in Fig. 2 part (h).

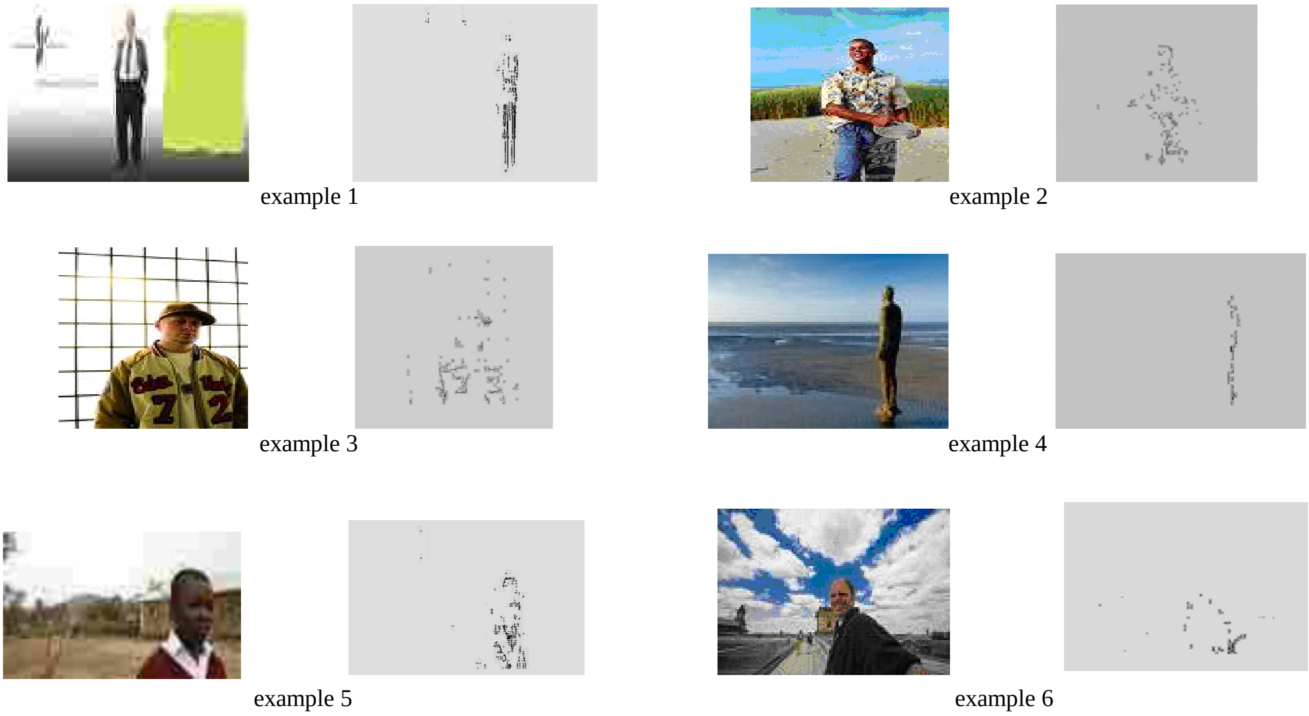

Fig. 5. Examples [8-9] for detecting the target location with 2D wavelet

VI. Target Motion Identification

A. Fifth Stage of the Algorithm

In this section we present the fifth stage of the algorithm. The main problem is already solved, in the other word; the target is identified and extracted from the background. At this stage the type of target motion is determined by angle classification and the average methods. In our algorithm by the target motion we mean any actions like sitting, standing, bending to the right, bending to the left and so done by the target. In this paper the Multilayer Perceptron Neural Network is used to identify the kind of motion based on the type of the decision and pattern recognition of motion. Multilayer Perceptron is the network by learning with the supervisor.

Structure of Perceptron neural network is shown in Fig. 4. In this type of neural network, network train by the inputs. Weights and biases of the Perceptron network are changed based on the errors occurred in the repetition of this action .the actions are repeated until the appropriate weights and biases are found to solve the problem.

As mentioned before, the target is extracted from the image in different positions and compared two by two with appropriate scale. As the result, we have an image that can give us the inputs of the neural network resulted from the average measures of top, bottom, left andright parts of the image. So the inputs are matrixes with 4 elements including the average light pixels of the top, bottom, left and right dimensions of the image. The output of the neural network is a numeral matrix representing the target modes including standing, sitting, bending to the right and bending to the left positions. Hardlim is selected as transfer function of the network used based on our needs.

To train the network a sufficient number of different images with different specified trainer (TARGET) are offered to the network. Moreover, a sufficient number of images are offered to the network to test the neural network to assure an ideal solution and the proper function of the network. Thus, the network is capable of making decisions based on the settings and inputs offered to it, and is also capable of make decisions for every unknown input mode (mode means the type of target motion) and motion pattern. As an example of the result of the algorithm performance, assume that the original image below is an input and it is desired to see how the algorithm can identify the target and how detect its state (mode).The example is shown in Fig. 3 [a-e]. All the stages of the algorithm are run based on the mathematical concepts and principles. These principles are listed in the references [23]-[27] along with the corresponding s and formulas under their subjects.

VII. Conclusions

In this paper, we propose the new algorithm for detecting a foreground moving target in an image with variable and complex Background which is an image containing moving objects. Our algorithm is tested on several numbers of different images. As shown, it is found by the results that the algorithm provides high performance and is complitly applicable for motion detection systems. As shown, the performance of wavelet transform to detect foreground moving target is surprisingly efficient. The novelty, new application of all stages of this algorithm, automaticity, intellectuality and ability of identifying a forgroand target despite many complexities existing in some images which cause errors in performance of other algorithms and motion detection systems are all reasons that discriminate our proposed algorithm from all the methods presented in the same area. Presenting a new method for boundary detection among the strength points is also another advantage of our algorithm.

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Farid Jafarian received the B.Sc. degree in Electrical Engineering, in 2008, from Isfahan Sepahan Institute of Science and Technology, Isfahan, Iran. Now he is student M.Sc. degree in Department of Electronics and Communications Engineering, communication systems, from October 2010 in University of Birjand, Birjand, Iran. His research interests include Communication and information theory and its applications, complexity reduction methods, coding and its applications to data transmission especially joint source and channel coding, communications signal processing especially video and speech coding, wireless communication and Telecommunication. He is currently working on Joint source and channel coding for video transmission over wireless communication, and research on its fundamental concept in information theory. Also he research on developing the cognitive radio systems. His email address is farid.jafarian@Birjand.ac.ir.

Raheleh Kafieh received the B.Sc. degree from Sahand University of Technology, Iran, in 2005 and the M.Sc. degree from the Isfahan University of Medical Sciences, Isfahan, Iran, in 2008, both in biomedical engineering. She is currently working toward the PhD degree in the Department of Biomedical Engineering at Isfahan University of Medical Sciences. She is member of medical image &signal processing research center (MISP), student member of the IEEE and the IEEE Signal Processing Society. Her research interests are in image and signal processing (especially biomedical image processing), pattern recognition, computer vision, graph algorithms, and sparse transforms. Her email address is r_kafieh@ resident.mui.ac.ir.