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Object Detection and Tracking on Three-Dimensional Images Based-on a New Multishape-Search- Pattern

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Abstract— Object detection and motion estimation are important issues in many different fields. They are widely and comprehensively used in military, robot industry, movie technology, medical field, and others. Therefore they have been the motivation of many research activities, through image and video processing. Among tens of available literature a number of approaches have been tried, but Block Matching, Optical Flow, and Block Flow are the famous techniques. This study introduces a new framework to deal with object detection and trajectory tracking problem, in a sequences of 3D ultrasound frames; firstly the traditional Block-Matching algorithm has been modified into a new multishape-search-pattern, and then we use combination of the modified-model and optical flow algorithm in a "cascade" to detect and determine the trajectory of the interested object. Atrial septal defect (ASD) has been selected as an object of case-study, and 3D ultrasound videos from "Khalifa-Hospital in Abu-Dhabi" were used as a data set, to evaluate the performance of the implemented algorithm. Comparative results show that the proposed scheme has a significant improvement in detecting and tracking ASDs, in terms of Peak Signal to Noise Ratio (PSNR) and computing velocity.

Index Terms—Block-Matching, Computer vision technology, Objects-Detection,

I. CONTEXT

Object tracking plays an important role in many computer applications, so introducing and implementing reliable and optimized object tracking scheme is the main objective of this work. Among tens of available literature; a number of approaches have been tried, but Block Matching, Optical Flow, and Block Flow are the famous techniques of object detection and tracking. Several Block Matching strategies have been implemented based on various algorithms such as fixed search pattern, variable search range, hierarchal and multi resolution, fixed search pattern algorithms, etc. [2]; techniques based on fixed search pattern algorithms have been extensively studied in this work (Koga et al. in 1981[2], Li, Zeng et al. in 1994 [3], L. M. Po et al. in 1996 [4], S. Zhu et al. in 2000 [5]. On the other hand Optical flow is the pattern of apparent motion of objects, surfaces, and edges in a visual scene caused by the relative motion between an observer, such as an eye or a camera, and the scene. It is the distribution of apparent velocities of brightness pattern movement in an image. [6], there are two of Optical flow algorithms: Lucas & Kanade algorithm witch is a solution of image registration [7] and the second is Horn-Schunck Algorithm in witch assumed that reflectance varies smoothly and has no spatial discontinuities, this assures them that the image brightness is differentiable.

Object's motion-estimation plays an essential factor in the assessing of patient with heart disorder, particularly, detecting and characterizing abnormalities in segmental wall motion function has become the hallmark of diagnosing coronary artery disease because reduced motion correlates with ischaemic muscle action [8]. In this paper we focus on detection and trajectory tracking of atrial septal defect (ASD) in 3D ultrasound frames sequences using a new modified framework. Atrial septal defect represent openings in the septum between the atria, which decrease the efficiency of heart pumping. [9].Ultrasound images present many difficulties in image processing because of the typically high level of noise found in them. For example, the tracking of cardiac walls in cardiac ultrasound images is difficult because of the high level of noise and also because of the nature of the cardiac motion. [8].

This paper describe a new reliable framework for ASD detection and tracking, in witch Block-Matching algorithm has been modified into a new multishape-search-pattern, and then a combination of this modified-model and optical flow algorithm in a "cascade" fashion has been implemented to detect and determine the trajectory of the interested ASD, experimental results show a significant improvement in Peak Signal to Noise Ratio (PSNR) values, and decreasing in the computations time, over the previous studies.

Next section of this paper describes the proposed new framework, while section (III) focuses on the implementation of the new framework and explorer the simulation results and discussions. Finally section (V) gives conclusions to this study and propose some future works.

II. DESIGN AND IMPLEMENTATION

A. Framework over view

In this section, we describe the proposed framework for detection, and tracking of ASD in 3D ultrasound video sequences. The framework combines two reliable "detection and tracking" algorithms in cascade structure. The detection algorithm is fully based-on the Block Matching Algorithm (BMA), in which a New Multishape-Search-Pattern (NMSP) was proposed and implemented the concept, the concept introduced in section (II. *C*). Then detected ASD; is robustly tracked through the ultrasound-video sequence by a modified optical-flow-algorithm as explained in section (II. *D*).

B. Dataset

To implement and test the proposed framework a 3D-Ultrasound ASD videos was collected from Sheikh-Khalifa Hospital Abu Dhabi and used, this dataset consists of 3D-Ultrasound video sequences in AVI format, 54 frame/second, and each frame with 956 x 716 pixels size.

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C. *Detection algorithm*

As introduced the framework consist of two major stages, the first stage of system is the detection of the object (ASD) within the frames of the ultrasound video sequence. We propose a novel detection scheme fully based-on the BMA using a new Multishape-Search-Pattern (NMSP). The idea behind block matching is to divide the current frame into a matrix of „macro blocks" and then compared with corresponding block and its adjacent neighbors in the previous frame to create a vector that stipulates the movement of a macro block from one location to another in the previous frame . The calculated movement for all macro blocks comprising a frame constitutes the motion estimated in the current frame. The search area for a good macro block match is constrained up to P pixels on all fours sides of the corresponding macro block in the previous frame. Usually the macro block is taken as a square of side 16 pixels, and the search parameter P is 7 pixels [10], Several Block Matching strategies have been implemented based on various algorithms such as fixed search pattern, variable search range, hierarchal and multi resolution, etc. [2].

In this study we have introduced a New Multishape-Search-Pattern, in witch there are three types of search patterns were considered; the first search is two shapes (semi-diamond, and diamond) in one pattern, constructed in 13 test points figure (1). And the second is square search pattern, witch was constructed in 9 test points figure (2), and finally we use diamond in 5 test-points search-pattern.figure (3).

D. *Search and Matching steps:*

Step1: the origin in the area of search is first set to a central search point in the two-in-one Search Pattern and the 12 coordinates. Next, Sum of Absolute Differences (SAD) values between the 12 candidate points and the central point around the block are calculated. If a minimum (SAD) value occurs at the central point, the process jumps to END; if not, then step 2 is executed.

Step 2, if the minimum error value occurs with one of the 12 coordinates, the position of the minimum (SAD) value searched at step 1 is set to a new central point in the 8-test-point Square-Search-Pattern; on the contrary, Next, Sum of Absolute Differences (SAD) values between the 8 candidate points and the central point around the block are calculated If the minimum (SAD) lies in the central point, a jump is made to END, otherwise step 3 is executed.

Step 3, if the minimum error value occurs with one of the 8 coordinates, the position of the minimum (SAD) value searched at step 2 is set to a new central point in the 5-test-point diamond-Search-Pattern; on the contrary, Next, Sum of Absolute Differences (SAD) values between the 5 candidate points and the central point around the block are calculated If the minimum (SAD) lies in the central point, a jump is made to END, otherwise step 3 is repeated.

END: Step 3 is the final solution of motion vector. The diamond is use in this final step and the (SAD) point obtained in this step is the central point of the best matching block.

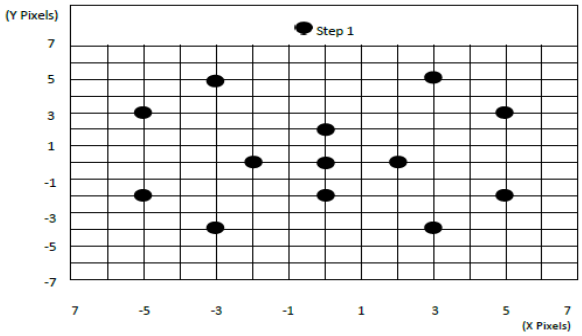


Figure (1): is a view illustrating Two-in-One Search Pattern

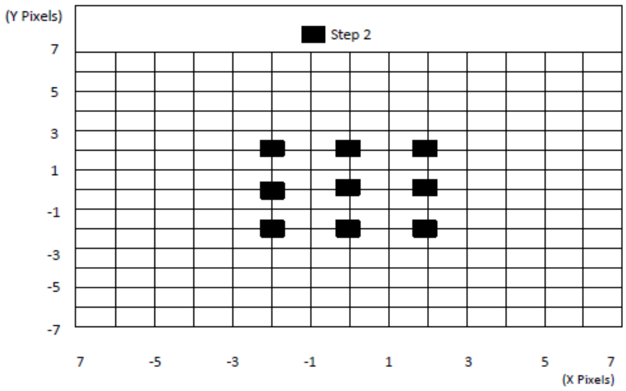


Figure (2): is a view illustrating Square Search Pattern

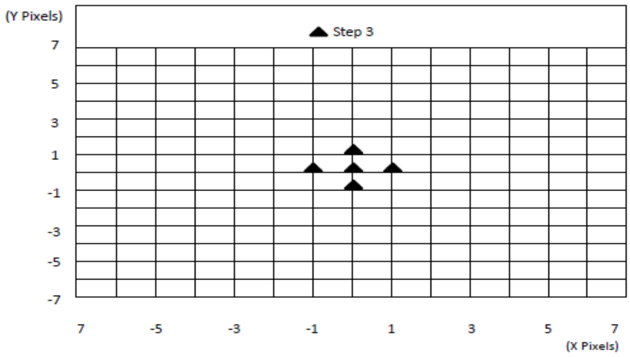


Figure (3): is a view illustrating Diamond Search Pattern

E. *Tracking algorithm*

Following detection of ASD in the ultrasound video sequence, a robust tracker is applied to increase the degree of determination and recognition of the ASD. Therefore our implemented tracking algorithm depends on the actual BMA outputs. In this stage we use optical flow to estimate motion vectors that describe the transformation from one frame to another. For a 3D (2D+t) dimensional image, a voxel at location (x,y,t) with intensity I(x,y,t) will have moved by Δx, Δy, and Δt between the two frames:

$$\frac{\partial I}{\partial x}\Delta x + \frac{\partial I}{\partial y}\Delta y + \frac{\partial I}{\partial t}\Delta t = 0 \qquad (1)$$

which results in

$$\frac{\partial I}{\partial x}V_x + \frac{\partial I}{\partial y}V_y + \frac{\partial I}{\partial t} = 0 \qquad (2)$$

Where:

V_x ,V_y the x and y components of the velocity or optical flow of I(x,y,t)

$\frac{\partial I}{\partial x}, \frac{\partial I}{\partial y}, \frac{\partial I}{\partial t}$ the derivatives of the image at (x,y,t) in the corresponding directions.

thus:

$$I_x V_x + I_y V_y = -I_t \qquad (3)$$

or

$$\nabla I^T.\vec{V} = -I_t \qquad (4)$$

We implemented Lucas-Kanade, in witch the optical-flow model can be assumed to hold for all pixels through a window. So, the motion vector (Vx,Vy) should satisfy:

$$I_x(q_1)V_x + I_y(q_1)V_y = -I_t(q_1) \qquad (5)$$
$$I_x(q_2)V_x + I_y(q_2)V_y = -I_t(q_2) \qquad (6)$$
$$I_x(q_n)V_x + I_y(q_n)V_y = -I_t(q_n) \qquad (7)$$

Where:

$q_1, q_2, \ldots, q_n$ are the pixels inside the window

The equations can be written in matrix form

$$\begin{bmatrix} V_x \\ V_y \end{bmatrix} = \begin{bmatrix} \sum_i I_x(q_i)^2 & \sum_i I_x(q_i)I_y(q_i) \\ \sum_i I_x(q_i)I_y(q_i) & \sum_i I_y(q_i)^2 \end{bmatrix}^{-1} \begin{bmatrix} -\sum_i I_x(q_i)I_t(q_i) \\ -\sum_i I_y(q_i)I_t(q_i) \end{bmatrix} \qquad (8)$$

Practically the ASD optical-flow tracker has been implemented with code-wise modification for acceptable video-resolution and less time computation, fig (4) bellow shows its flowchart.

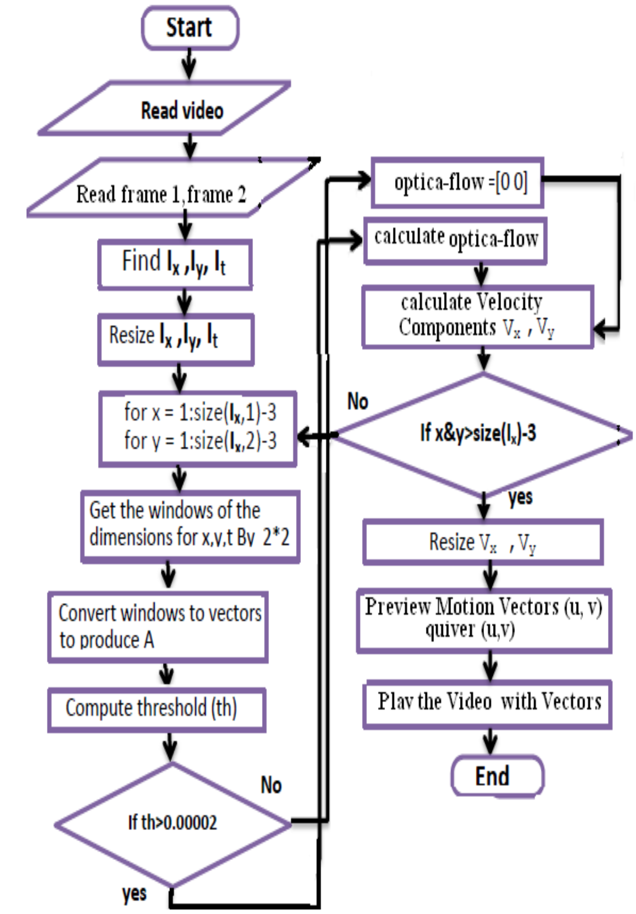


Figure (4): Multishape-Search-Pattern flowchart

IV. RESULTS

To assess the proposed framework we have used the dataset mentioned in section (II. *B*), and Matlab version 7.10.0 (R2010a) for implementation the algorithms.

A. Detection Performance Results

Execution-time and Peak Signal to Noise Ratio values are computed as comparative metrics for the ASD 3D-images using the three correlation-baseline algorithms; Three Step Search (TSS), New Three Step Search (NTSS), Four Step Search (4SS), and our new Multishape-Search-Pattern (MSSP) that has been described in section (II.*C*). The detection and tracking quantitative results are shown in Table 1; the maximum PSNR score represents the best match, while minimum code execution-time represents the best algorithm, in terms of PSNR our algorithm performed better than the others, but it scored the second-best among the four implemented algorithms with respect to execution-time.

1) Peak Signal to Noise Ratio (PSNR)

The PSNR is mostly used as a performance factor to evaluate a video quality, it defined via the mean squared error MSE which for two frames; I and K where one of the frames is considered as reference.

$$\text{MSE} = \frac{1}{mn}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1} \|I(i, j) - K(i, j)\|2 \qquad (9)$$

$$\text{PSNR} = 10.\log10\left(\frac{(MAXI)2}{MSE}\right) = 20.\log10\left(\frac{MAXI}{\sqrt{MSE}}\right) \qquad (10)$$

Where, MAXIis the maximum pixel value in the frame.

2) Framework Execution-time

The execution time of a certain algorithm; is a time that spent by the system process that algorithm, in our system it includes the time of reading videos, enhancement, detection (matching) the ASD, and motion vector estimation

Table 1 PSNR and Execution-time scores using the four detecting *techniques*

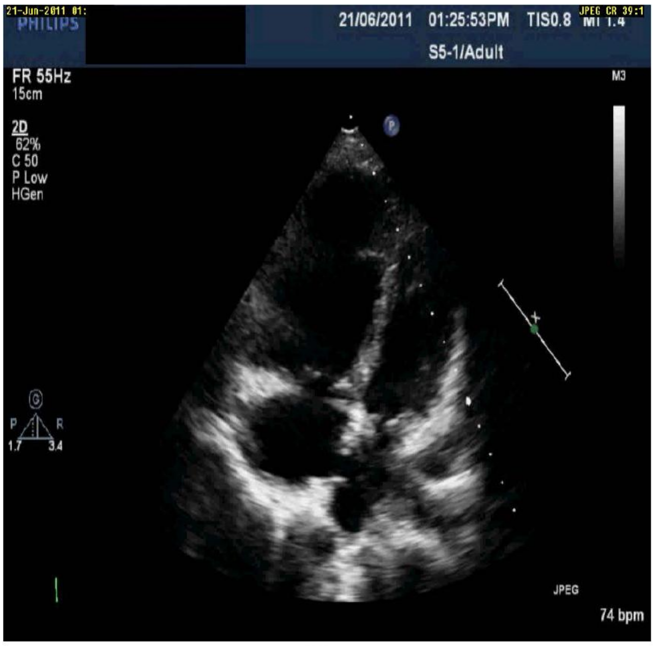
Detection Method	PSNR	Execution-time (sec)
(MSSP)	23.3866	7.9405
TSS	21.3601	5.6628
4SS	17.4292	8.3461
NTSS	23.5918	8.6021

B. Tracking Performance Results

Figure (5) presents the performance results of the new Multishape-Search-Pattern detection algorithm; witch is visually more robust and acceptable, and shows superior results of our tracking technique.

V. CONCLUSION:

In this study, we have proposed a reliable and acceptable framework for detection and tracking objects in 3D ultrasound frames. Atrial septal defect (ASD) has been selected as an object of case-study. Detection is handled by a New Multishape-Search-Pattern; a modified optical was implemented to track and estimate the blood follow. The methodology and implementation is clearly explained in Section (II), and the capability and significance of the work have been demonstrated in section (III). Results in 3D-ultrasound frames present the validity of the introduced method as competitive results quality-wise, and a significant gain speed-wise.



(a)

(b)

Figure (5): ultrasound frames of a heart with ASD. The image (a) “top” represent the original frame in AVI format with 956 x 716 pixels size, while image (b) “bottom” view the detected ASD in a green rectangular and to track the blood flow in a directed moving-arrows.

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