Shape Transformation of Left Ventricle Wall for Cardiac Global Hypokinetic Evaluation

Adhi Harmoko Saputro$^1$, Mohd. Marzuki Mustafa$^2$, Aini Hussain$^3$, Oteh Maskon$^4$ and Ika Faizura Mohd Nor$^5$

$^6$ Department of Electrical, Electronic and Systems Engineering
Universiti Kebangsaan Malaysia, Bangi 43600, Malaysia
Email: $^1$adhi.harmoko@ui.ac.id, $^2$marzuki@vlsi.eng.ukm.my, $^3$aini@vlsi.eng.ukm.my
$^4$ The Cardiac Care Unit, Medical Center
Universiti Kebangsaan Malaysia, Kuala Lumpur 56000, Malaysia
Email: $^4$auajwad@yahoo.com, $^5$azuzayz@yahoo.ie

Abstract—A method to evaluate left ventricular (LV) wall motion in two-dimensional (2D) echocardiographic image is proposed. It is used to investigate posterior and anterior septum wall shape change while pumping the blood in human cardiac. Shape transformation parameters of myocardial wall boundary were extracted to indicate the LV wall movement from end diastole to end systole. Quantitative parameters represent the movement of LV wall segment whatever translation, rotation, expansion or combination of them. Initial myocardial boundary is drawn manually on end diastole cycle and then tracked to all frames by computing the speckle motion estimation in each frame of cardiac cycle. The motion vector of myocardial boundary movement is computed using warping optical flow on wavelet multi-resolution. The method was applied to parasternal long axis view of 2D echocardiographic from normal subject and patients with global hypokinetic. The results show that quantitative evaluation parameters gave a potential indication in evaluating and diagnosing myocardial wall motion abnormalities.

Keywords—myocardial motion, echocardiographic, shape transformation, motion estimation.

I. INTRODUCTION

Currently, the left ventricular (LV) wall motion can be analyzed on three schemes namely qualitative, semi-quantitative and quantitative assessment. Eyeball assessment, normal-abnormal comparison and normal-hypokinetic-akinetic-dyskinetic scheme are classified as quantitative assessment. Wall motion score index is classified as semi-quantitative assessment. Whereas for accurate assessment can be done by measuring left ventricle regional quantitatively which analyze global function as a percentage of normal condition such as radial and fractional shortening [1], fractional cavity area change, chordal centerline analysis, wall velocity, myocardial displacement [2], myocardial gradient, strain and strain rate [3, 4].

The term hypokinetic is used for the motor function of muscle that performs below normal condition. In cardiac disease, hypokinetic is classified as ischemic disease which caused by a chronic lack of oxygen in coronary artery. Hypokinetic is one of dysfunction of the left ventricle. It means some segments of the myocardium are in low contraction function. Whereas, the term global hypokinetic is used to indicate all segment of the myocardium in low contraction function.

In the previous works, the motion estimation on echocardiographic image using optical flow and wavelet decomposition has been described [5]. In this technique, two dimensional motion vectors was generated accurately on parasternal long axis view of human cardiac for both case normal subject and hypokinetic patients. The abnormalities evaluation of left ventricle wall motion is hardly difficult tasks, due to it is performed visually based on the motion vector near the LV wall. To make it useful for diagnosis purposes, it is important to find some quantitative representation for the wall vector motion.

In this work, we proposed shape transformation parameters for the quantitative evaluation of the LV wall motion. The shape transformation parameters are obtained by finding transformation matrix between initial boundary wall and final boundary wall. In particular, we investigate the ability of
shape transformation parameters to assess the shape pattern in
global hypokinetic case. This assessment is performed on 2D
echocardiographic image from twelve normal subject and
three patients with global hypokinetic.

II. METHODOLOGY

In this section, the detail of methodology of cardiac global
kinetic evaluation using LV wall shape transformation is
explained.

A. Cardiac shape transformation

Let \( X_0(x, y) \) be the initial position of any point in first frame
of a image sequence where \( x \) and \( y \) indicate the horizontal and
vertical position in Cartesian coordinate. This point can be
transformed into a new point using transformation functional
form \( T \) as follow

\[
X_t = T \cdot X_0
\]

where \( X_0 \) is initial point of \( x_0, y_0 \) and \( X_t \) is final point of \( x_t, y_t \).

In shape transformation, the initial position \( X_0 \) can be
consist a number of points which create a shape and can be
written as follow

\[
[X_1 X_2 X_3 \cdots X_n] = T[X_1 X_2 X_3 \cdots X_n]
\]

In the 2D geometric transformation, the functional form \( T \)
can be represented using a 2x2 matrix for most common
transformation such as linier, rotation, scaling, shearing,
reflection and orthogonal (see Table 1). The complex
transformation can be generated by combine several
transformations using simple matrix multiplication of each
functional form.

TABLE I

2x2 MATRIX FOR MOST COMMON TRANSFORMATION

<table>
<thead>
<tr>
<th>Transformation</th>
<th>Functional form ( T )</th>
<th>Information</th>
</tr>
</thead>
</table>
| Linier                  | \[
| \begin{bmatrix} x & 0 \\ 0 & y \end{bmatrix} \] | \( x = \) horizontal \( y = \) vertical |
| Counter-clockwise rotation | \[
| \begin{bmatrix} \cos \theta & \sin \theta \\ -\sin \theta & \cos \theta \end{bmatrix} \] | \( \theta = \) rotation angle |
| Clockwise rotation      | \[
| \begin{bmatrix} \cos \theta & -\sin \theta \\ \sin \theta & \cos \theta \end{bmatrix} \] | \( \theta = \) rotation angle |
| Scaling                 | \[
| \begin{bmatrix} S_x & 0 \\ 0 & S_y \end{bmatrix} \] | \( S_x = \) horizontal \( S_y = \) vertical |
| Shearing                | \[
| \begin{bmatrix} 1 & k \\ 0 & 1 \\ 1 & 0 \\ k & 1 \end{bmatrix} \] | Parallel to the \( x \) axis \( \) (Parallel to the \( y \) axis) |

In general, the human cardiac has several motion directions
that occurs in the cardiac cycle such as radial movement
(expansion or contraction), horizontal rotation (clockwise or
counter clockwise) and vertical rotation (upward or downward)
[6]. Combining this motion directions into a standardized
division of the left ventricle according to the American Heart
Association [7], motions that depicted using the short axis
view have radial and horizontal motion. Whereas, radial
motions is depicted using the long axis view. Figure 1 shows
the visualisation of motion direction in each cardiac view.

The shape change as shown in figure 1 that caused by
cardiac muscle motion can be represented as a 2D geometric
transformation. Expansion and contraction motion can be
represented as linier or scaling transformation whereas
upwards and downwards motion can be generated by
combination of rotation and scaling transformation. This
representation of shape transformation and shape change of
myocardium inspired a method that use shape transformation
parameter to evaluate the wall motion abnormalities.

B. Computing transformation parameters

Transformation parameters of myocardial boundary that
used to evaluate the wall motion abnormalities are generated
by computing the shape transformation of myocardial wall in
en end systole and in end diastole. Moreover these parameters
are used to describe the left ventricle contraction performance
while pumping the blood. Scaling value in transformation
matrix can be substituted the left ventricular ejection fraction
(LVEF) that has established for cardiac abnormalities
evaluation as in [8].

 Detail of transformation parameters computation is
described by Figure 2. Computation process of these
parameters is performed as follow. A set motion vector of all
frames was generated using optical flow on wavelet multi-
resolution [5]. This motion estimation was used due to its
accuration in estimating \( u \) and \( v \) velocity in speckle noisy
image. Cardiologist should draw the initial boundary by a
number of points along the septum and the posterior in first
frame of sequence (end diastole). The final boundary was

708
formed by tracking initial point to last frame of sequence (end systole) by computing the point movement based on the velocity that generated by the motion estimation. Finally, there are two shapes of myocardial boundary, diastole wall shape (first frame) and systole wall shape (last frame).

Myocardial boundary tracking from end diastole to end systole was performed based on the velocity motion field that computed using generated using optical flow on wavelet multi-resolution [5]. Figure 3(a) shows the motion vector of the normal subject that superimposed to its first frame of echocardiographic image sequences. Moreover figure 3(b) shows the example of initial boundary (yellow line) and the final boundary (green line) of global hypokinetic patient that superimposed to its last frame of echocardiographic image.

![Flowchart of shape transformation parameters computation in left ventricle wall on 2D echocardiographic image](image)

**Fig. 2** A flowchart of shape transformation parameters computation in left ventricle wall on 2D echocardiographic image

Transformation parameters of both shapes are computed by arrange the points as follow

\[
\begin{bmatrix}
X_1 & X_2 & \cdots & X_n
\end{bmatrix}_s - T \begin{bmatrix}
X_1 & X_2 & \cdots & X_n
\end{bmatrix}_d = 0
\]  

(3)

where \(\begin{bmatrix}
X_1 & X_2 & \cdots & X_n
\end{bmatrix}_s\) is a set point in end systole and \(\begin{bmatrix}
X_1 & X_2 & \cdots & X_n
\end{bmatrix}_d\) is a set point in end diastole. Both of set points must be same in dimension.

Equation 3 can be solved using least square equation solution to find the transformation matrix \(T\) as follow

\[
T = \begin{bmatrix}
S_x & S_o \\
S_y & S_y
\end{bmatrix}
\]  

(4)

where \(S_x\) is horizontal scaling factor, \(S_y\) is vertical scaling factor and \(S_o\) should be near zero (\(S_o \approx 0\)).

III. RESULT AND DISCUSSION

The experiment result of the cardiac evaluation with normal subject, patient with global hypokinetic, shape transformation computing and physical meaning of parameters is presented in this section.

The echocardiographic data were acquired from twelve normal subjects and three patients with global hypokinetic using Acuson Sciovia C512 Ultrasound Machine at Cardiac Care Unit UKM Medical Centre. These echocardiographic data had a width and height of 384×287 pixels and recorded in dicom medical image format to preserve the speckle information.

A. Myocardial Boundary Tracking
versus global hypokinetic ($S_x = 0.96 \pm 0.01$). The vertical scaling factor also resulted in significant differences between normal ($S_y = 0.84 \pm 0.05$) versus global hypokinetic ($S_y = 0.95 \pm 0.04$).

![Graph showing mean and standard deviation for shape transformation (T) in x and y directions in normal and global hypokinetic cases.](image)

Fig. 4. Mean and standard deviation for shape transformation (T) in x and y directions in normal and global hypokinetic cases.

The shape transformation parameters ($S_x$ and $S_y$) have physical meaning regarding the movement of myocardial segment. These parameters are scaling factor of shape transformation. If the scaling factor is lower than one, the shape is smaller than the previous one. Otherwise the scaling factor is higher than one; the shape is bigger than the previous one. While the blood pumping process at the end of diastole to the end of systole, the volume of left ventricle is decline. In other word, the myocardial boundary is shrinking in this process. The normal subject should have bigger shrinking than the hypokinetic patient. Figure 4 show that the normal subjects have S parameters more than global hypokinetic. This agrees with the left ventricular ejection fraction (LVEF) which the normal subject have the LVEF at 69.6±7.4% for men and 67.8±7.2% for woman [10] whereas the abnormal contraction function has the LVEF less than 40%.

IV. CONCLUSIONS

In this paper, a method to evaluate cardiac global hypokinetic using shape transformation parameters has been presented. This method exploits the transformation matrix of myocardial boundary shape change as a reference to detect left ventricular abnormalities especially in global hypokinetic patient. The experiment result obtained with real clinical data from normal subject and patient with global hypokinetic express the ability of the method to evaluate the left ventricle contraction abnormalities. It may also be interesting that quantitative evaluation parameters gave a potential indication in evaluating and diagnosing all myocardial wall motion abnormalities.

ACKNOWLEDGMENT

The authors would like to acknowledge Universiti Kebangsaan Malaysia (Project code UKM-GUP-TKP- 08-24-080) for the financial support awarded for this research.

REFERENCES


