Image Enhancement of Ultrasonic Image for Vision Based Computer Aided Cardiac Diagnosis System

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BACKGROUND

• Myocardial infarction (heart attack) -> main cause of death
  – WHO: 12.6% of death throughout the world in 2002
  – In Malaysia: 650,000 case in 2004
  – 17 million die/year caused by CVD (heart attack and stroke)
  – men: no 2 after AIDS
  – women: no 3 after bipolar syndrome & AIDS
BACKGROUND

• Heart attack occurs -> blood supply of heart is interrupted
  – due to (CHD)
• Early detection of CHD -> by detecting motion abnormality of left ventricular (LV) of the heart.
• motion of LV is fully analyzed by cardiologist (expert knowledge and vast experiences)
  – differentiate between normal and abnormal LV motion.
• Needs automation (CADiag)

Blood Circulation
Blood Circulation

Medical Imaging

- USG
- Roentgen Machine (X-Ray)
- CT-Scan
- PET
- MRI
Ultrasound imaging

Advantages:

• Among various imaging system:
  – Cheap operating & capital costs
  – Low safety requirements
  – More acceptable by patients

• -> most widely used

Disadvantages:

• Contains speckle noise
  – Random granules, generated from ultrasound waves interaction
• Degrades its quality
• Difficult for diagnosis
• Needs image processing
Speckle noise elimination/reduction

- Mean & Gaussian smoothing
- Median filters
- Speckle Reduction Imaging (SRI) [Liasis et al., 2008]
- Maximum a posterior (MAP)
- Wavelet based filters [Rallabandi, 2008]
- Anisotropic diffusion (AD) [Munteanu et al., 2008]
- Morphological filter [Filho et al., 2004]

→ most of them using single image

- Spatial domain
- Frequency domain

Developed techniques

- Enhanced Anisotropic Diffusion with Noise Amplification Suppression (ICSIPA 2009)
- Warped Anisotropic Diffusion of Ultrasound Image (TENCON 2009)
- Inter-frame Enhancement of Ultrasound Images Using Optical Flow (LNCS Springer 2009)
- Bidirectional Optical Flow Inter-Frame Technique for Ultrasound Video Enhancement (WCE 2010)
Enhanced Anisotropic Diffusion with Noise Amplification Suppression

Anisotropic diffusion

- Developed from gaussian filter
- Make use of diffusion mechanism in heat conduction

\[ I_t = \text{div}(c \nabla I) \]

- Use non-uniform conduction coefficient
  - Intra region
  - edge

\[ I_t = \text{div}(c(|\nabla I|)\nabla I) \]
**Anisotropic diffusion**

**Isotropic diffusion**

**Conductance function**

- **PM1**
  \[ \sigma(dI) = e^{-\left(\frac{dI}{\kappa}\right)^2} \]

- **PM2**
  \[ \sigma(dI) = \frac{1}{1 + \left(\frac{dI}{\kappa}\right)^2} \]

- **EAD**
  \[ \sigma(dI) = LoG(dI) = \left(1 - \left(\frac{dI}{\kappa}\right)^2\right) e^{-\left(\frac{dI}{\kappa}\right)^2} \]
Conductance function

\[ c_{EADNAS}(dI) = \begin{cases} c_{EAD}(dI), & \text{if edge} \\ 1, & \text{if noise explosion} \end{cases} \]
Test images

No noise

5% noise

10% noise

15% noise

20% noise

Result

PM1, Kappa = 50
Result

PM2, Kappa = 50

EAD, Kappa = 50

Result

EAD, Kappa = 60

EAD, Kappa = 70
Result

EAD, Kappa = 80  EAD, Kappa = 90

Conclusion

- Proposed method (Enhanced Anisotropic Diffusion) is able to eliminates noise while enhancing edges
Warped Anisotropic Diffusion of Ultrasound Image

An example of ultrasound image
Pixel Grid

The schematic diagram of the proposed technique

Original image

Warping

Anisotropic Diffusion

Dewarping

Processed image

Processed image (a) (b)
Coordinate system of the grids

Experiments
- scatterer model of a kidney
- anisotropic diffusion of the original image
Experiments

scatterer model of a kidney

ultrasound image

anisotropic diffusion of the original image

PSNR of the Images

<table>
<thead>
<tr>
<th>Image</th>
<th>PSNR (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultrasound</td>
<td>12.48</td>
</tr>
<tr>
<td>Anisotropic Diffusion (AD)</td>
<td>12.97</td>
</tr>
<tr>
<td>Warped Anisotropic Diffusion (WAD)</td>
<td>13.15</td>
</tr>
</tbody>
</table>
The visual observation and quantitative evaluation of the PSNR using simulated ultrasound image of a kidney demonstrate that the proposed WAD gives better result than the mere AD technique.

Conclusion
INTER-FRAME ENHANCEMENT OF ULTRASOUND IMAGES USING OPTICAL FLOW

SPECKLE NOISE ELIMINATION/REDUCTION

- Mean & Gaussian smoothing
- Median filters
- Speckle Reduction Imaging (SRI) [Liasis et al., 2008]
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  + Spatial domain
  + Frequency domain
SPECKLE NOISE ELIMINATION/REDUCTION

- SNR: signal to noise ratio
- main idea: improve SNR
  - decrease noise
  - increase signal
    - information from neighboring pixels
      - single frame
    - information from multiple image
      - multiple frames

MULTIPLE FRAME TECHNIQUES

- static scene
  - lengthen acquisition time
- dynamic scene (moving object)
  - multiple acquisition of single scene
    - cyclic movement
    - cardiac: systole-diastole
  - utilizing consecutive scenes
    - frame reconstruction
MULTIPLE FRAME TECHNIQUES

- Speckle reduction using biased motion-adaptive temporal filtering [Evans et al., 1996]
- Motion-guided anisotropic filtering [Grau and Noble, 2006]
- Eliminating part in the frame that suffered from abnormal lighting [Coleshill et al., 2007]
- Enhancement technique based on convex projection of inter-frame coded images [Jung et al., 1999]

PROPOSED TECHNIQUE

- Enhancement technique for ultrasound images using 3 consecutive frames
  - extracted from an ultrasound video
- Main idea: provide a second image to the image being enhanced
- utilizes optical flow
  - enhance middle frame based on preceding and the following frames
PROPOSED TECHNIQUE

\[ \vec{W} = \frac{\vec{v}}{2} \]

\[ I_{\text{Intermediate}}(P') = I_{\text{Previous}}(P) \]

\[ I_{\text{Enhanced}}(P') = \max(I_{\text{Current}}(P'), I_{\text{Intermediate}}(P')) \]
RESULT AND DISCUSSION

3 consecutive frames

RESULT AND DISCUSSION

reconstructed frame

Lukas-Kanade optical flow
Horn-Schunck optical flow
RESULT AND DISCUSSION

- Lukas-Kanade, average
- Horn-Schunck, average
- Lukas-Kanade, maximum
- Horn-Schunck, maximum

enhanced frame

RESULT AND DISCUSSION

- intensity profile

original
CONCLUSION

- proposed technique to enhance ultrasound images using 3 consecutive frames
  - extracted from an ultrasound video
- uses optical flow algorithm to reconstruct an intermediate frame
  - based on the preceding and the following frames
- the reconstructed image is used to enhance the middle frame
  - image fusion
- best result: using Lukas-Kanade optical flow and average operator
FUTURE WORKS

- combine forward-backward optical flow
- extrapolation instead of interpolation
  - forward & backward
- utilize even more frames
  - non-linear interpolation
    - polynomial
    - spline

BIDIRECTIONAL OPTICAL FLOW INTER-FRAME TECHNIQUE FOR ULTRASOUND VIDEO ENHANCEMENT
Thank you