Image Enhancement of Ultrasonic Image

for Vision Based Computer Aided Cardiac Diagnosis System

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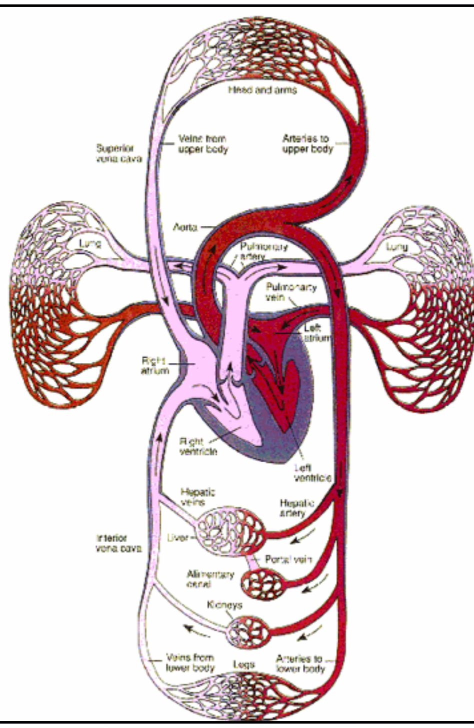
BACKGROUND

- 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 attck and stroke)
  - men: no 2 after AIDS
  - women: no 3 after bipolar syndrome & AIDS

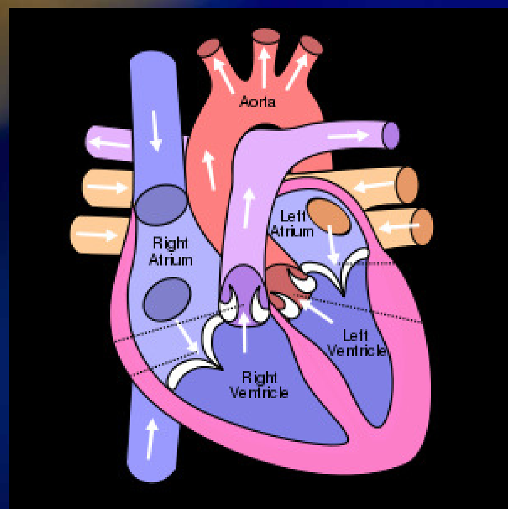
BACKGROUND

- 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

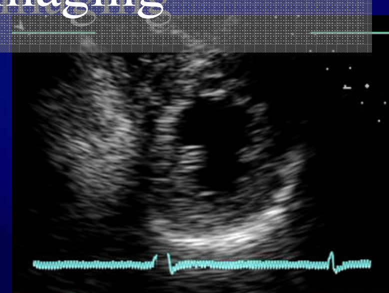
Advantages:

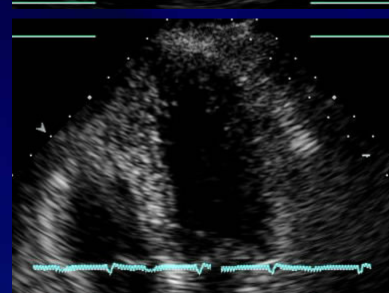
- Among various imaging system:
  - Cheap operating & capital costs
  - Low safety requirements
  - More acceptable by patients
- -> most widely used

Ultrasound imaging

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]
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- Morphological filter [Filho et al, 2004]

→ most of them using single image
  - Spatial domain
  - Frequnecy 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

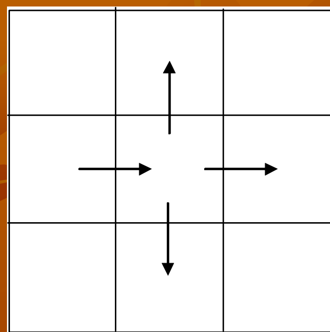
Anisotropic diffusion

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

$$I_t = div(c\nabla I)$$

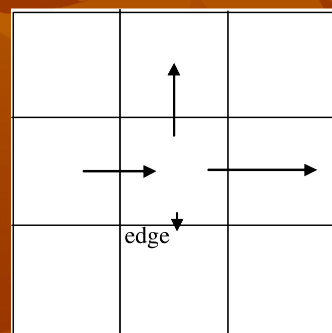
- Use non-uniform conduction coefficient
  - Intra region
  - edge

$$I_t = div(c(|\nabla I|)\nabla I)$$



Isotropic diffusion

Anisotropic diffusion



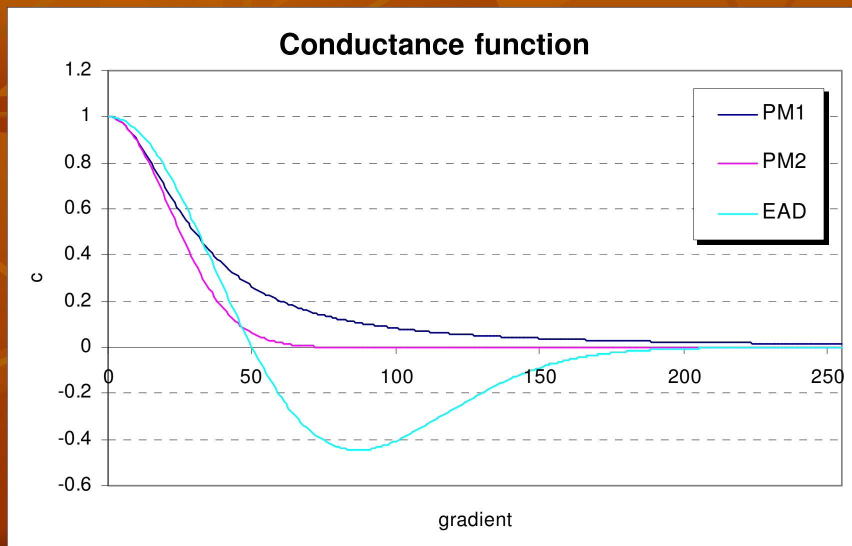
Conductance function

PM1 $$c(dI) = e^{\left(-\left(\frac{dI}{\kappa}\right)^2\right)}$$

PM2 $$c(dI) = \frac{1}{1+\left(\frac{dI}{\kappa}\right)^2}$$

EAD $$c(dI) = LoG(dI) = \left(1-\left(\frac{dI}{\kappa}\right)^2\right)e^{\left(-\left(\frac{dI}{\kappa}\right)^2\right)}$$

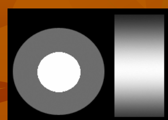
Conductance function



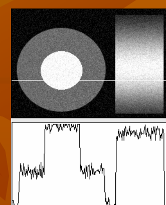
Noise explotion suppression

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

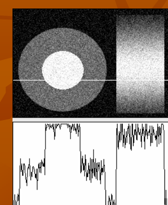
Test images



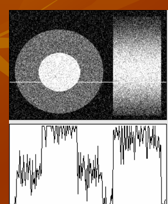
No noise



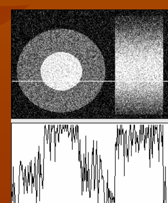
5% noise



10% noise

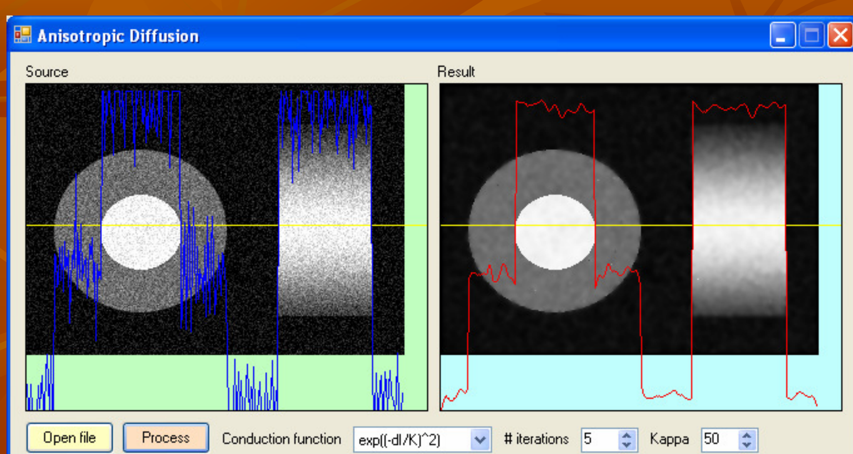


15% noise



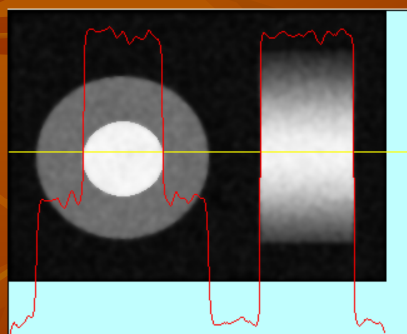
20% noise

Result

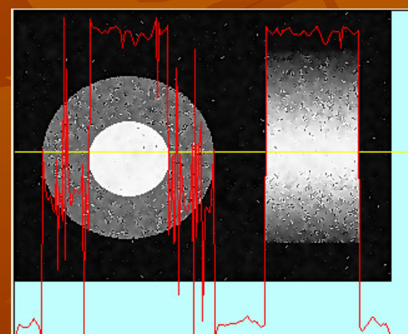


PM1, Kappa = 50

Result

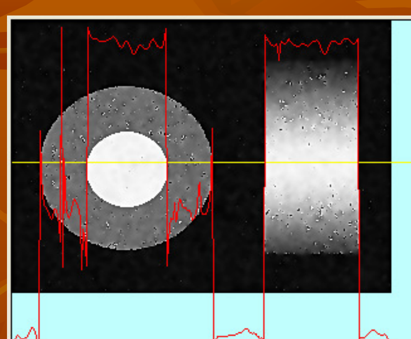


PM2, Kappa = 50

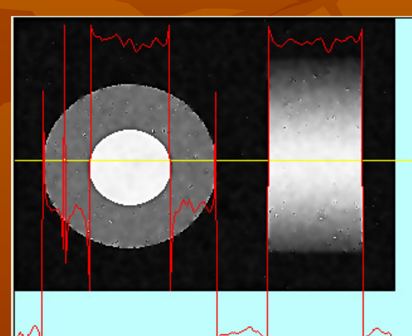


EAD, Kappa = 50

Result

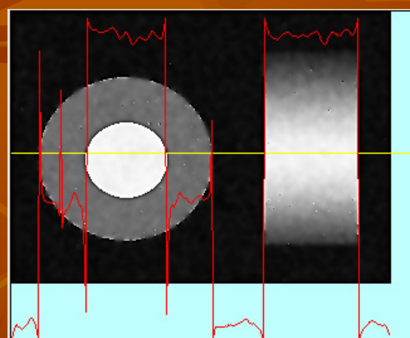


EAD, Kappa = 60

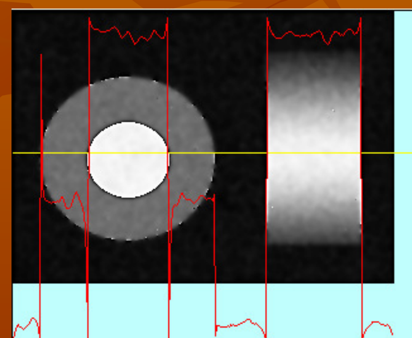


EAD, Kappa = 70

Result



EAD, Kappa = 80



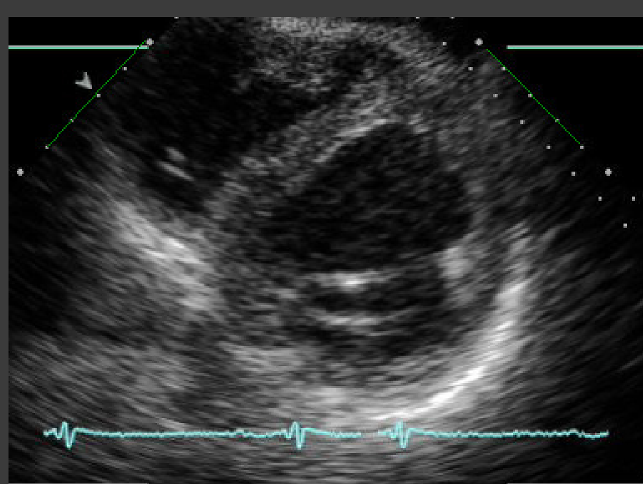
EAD, Kappa = 90

Conclusion

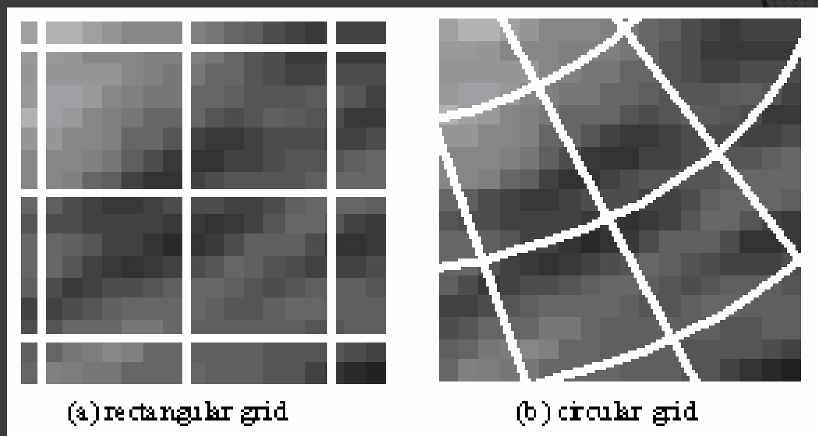
- Proposed method (Enhanced Anisotropic Diffusion) is able to eliminates noise while enhancing edges

Warped Anisotropic Diffusion of Ultrasound Image

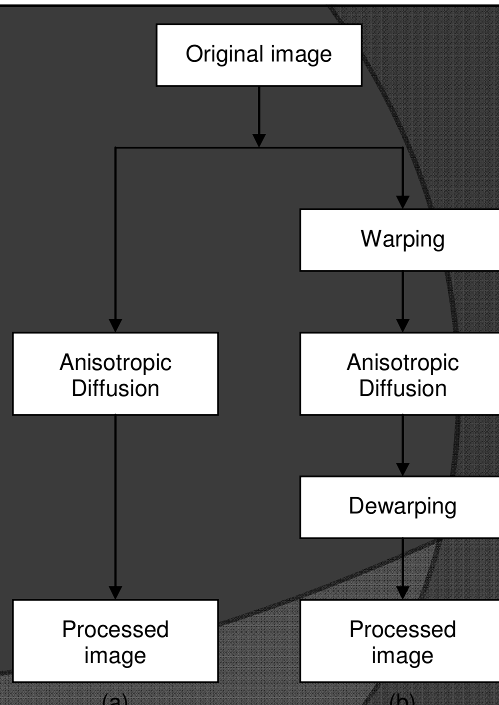
An example of ultrasound image



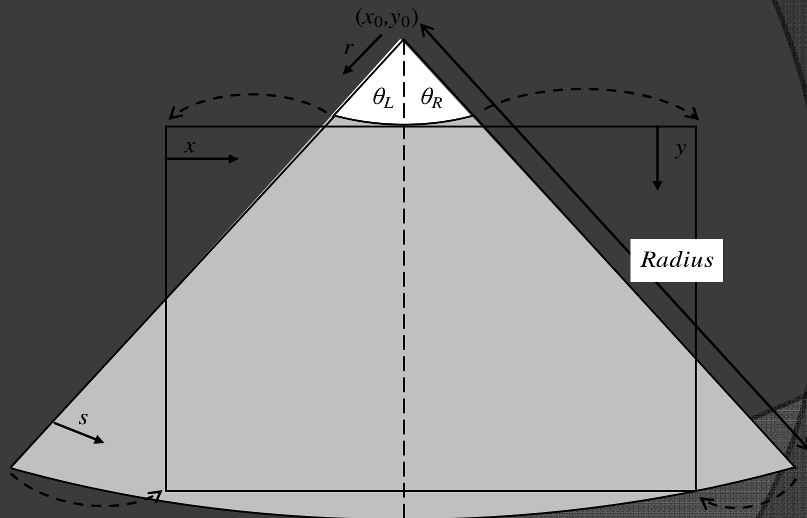
Pixel Grid



The schematic diagram of the proposed technique



Coordinate system of the grids



Experiments

scatterer model of a kidney

ultrasound image

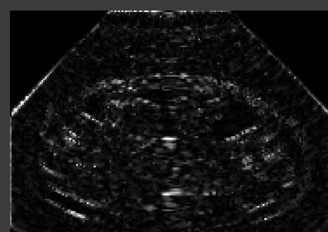
anisotropic diffusion of the original image

ultrasound image

Experiments

scatterer model of a kidney

ultrasound image

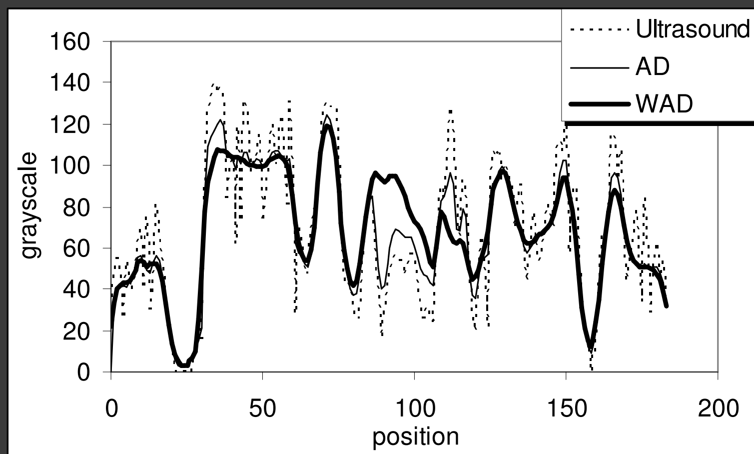


anisotropic diffusion of the original image

PSNR of the Images

Image	PSNR (dB)
Ultrasound	12.48
Anisotropic Diffusion (AD)	12.97
Warped Anisotropic Diffusion (WAD)	13.15

Grayscale profile at row 105



Conclusion

- 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.

INTER-FRAME ENHANCEMENT OF ULTRASOUND IMAGES USING OPTICAL FLOW

SPECKLE NOISE ELIMINATION/REDUCTION

- Mean & Gaussian smoothing
- Median filters
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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

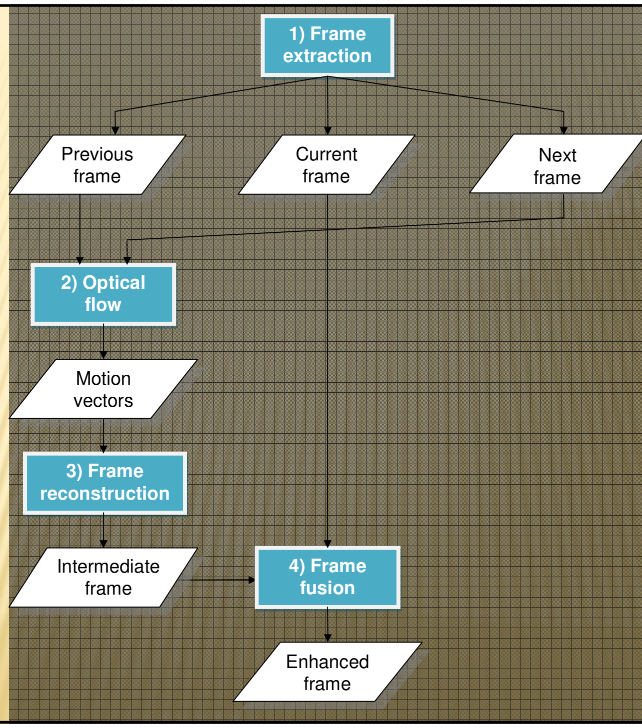
MULTIPLE FRAME TECHNIQUES

- 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]

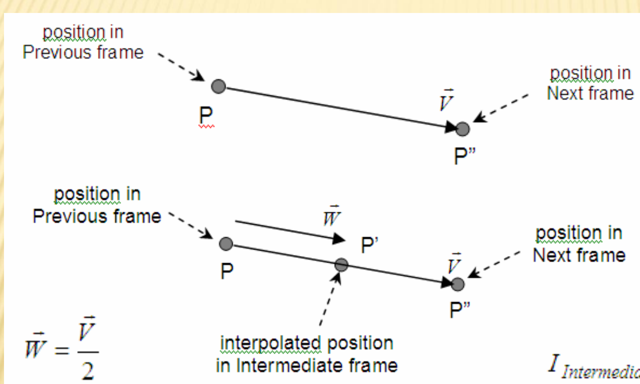
PROPOSED TECHNIQUE

- 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

Flowchart



PROPOSED TECHNIQUE

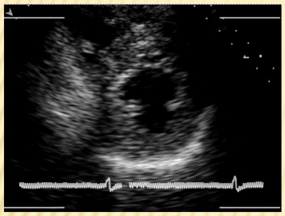


$$I_{Intermediate}(P') = I_{Previous}(P)$$

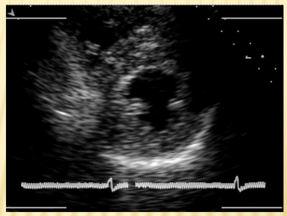
$$I_{Enhanced}(P') = \frac{I_{Current}(P') + I_{Intermediate}(P')}{2} \quad .$$

$$I_{Enhanced}(P') = \max(I_{Current}(P') + I_{Intermediate}(P'))$$

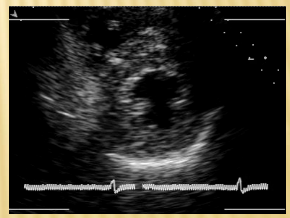
RESULT AND DISCUSSION



Previous



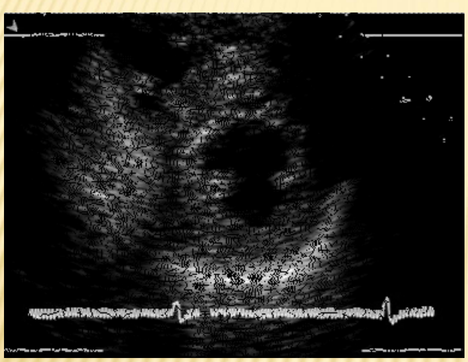
Current



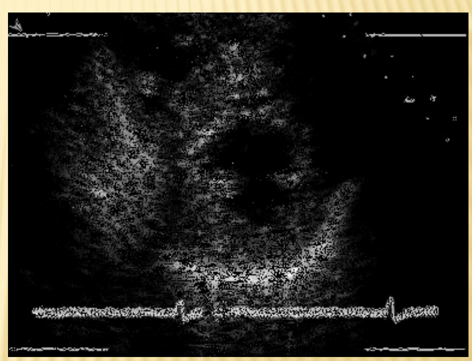
Next

3 consecutive frames

RESULT AND DISCUSSION



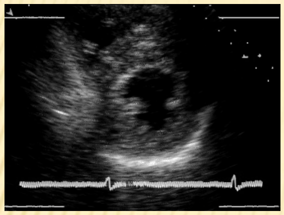
Lukas-Kanade optical flow



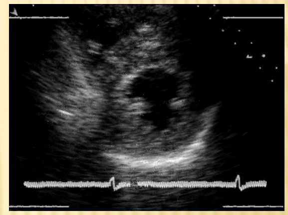
Horn-Schunck optical flow

reconstructed frame

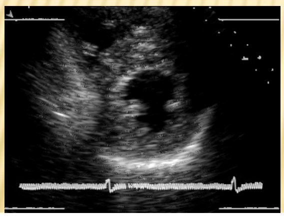
RESULT AND DISCUSSION



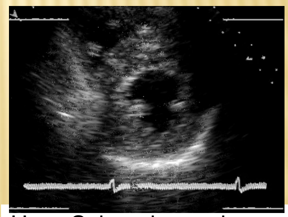
Lukas-Kanade, average



Horn-Schunck, average



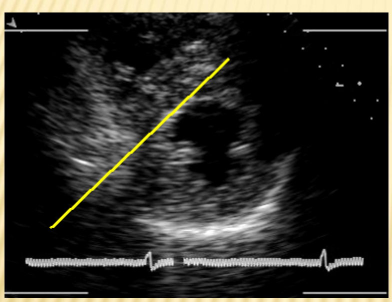
Lukas-Kanade, maximum

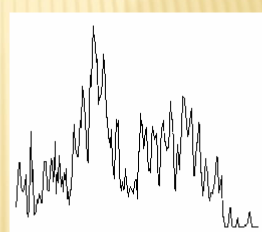


Horn-Schunck, maximum

enhanced frame

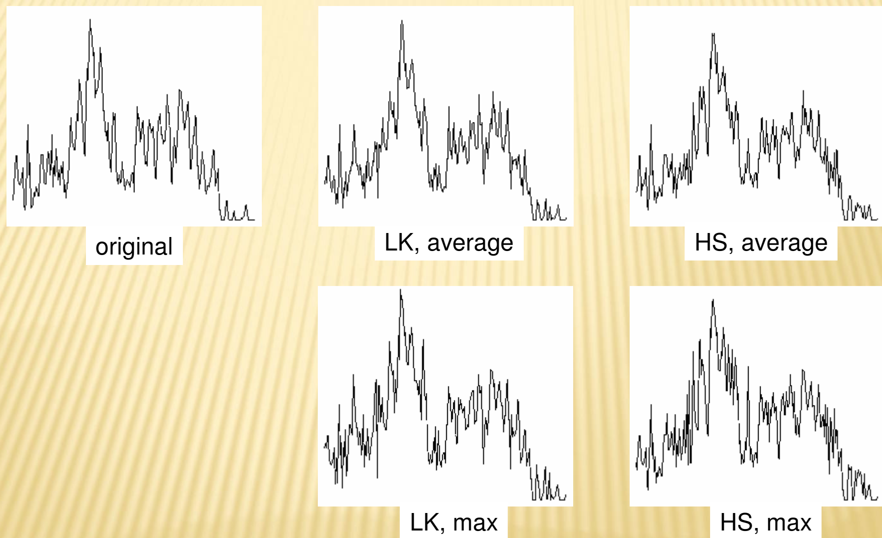
RESULT AND DISCUSSION





original

intensity profile



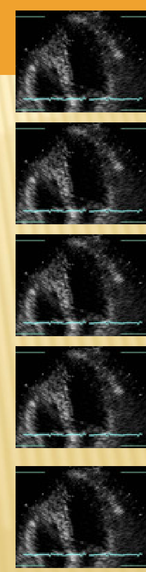
intensity profile

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

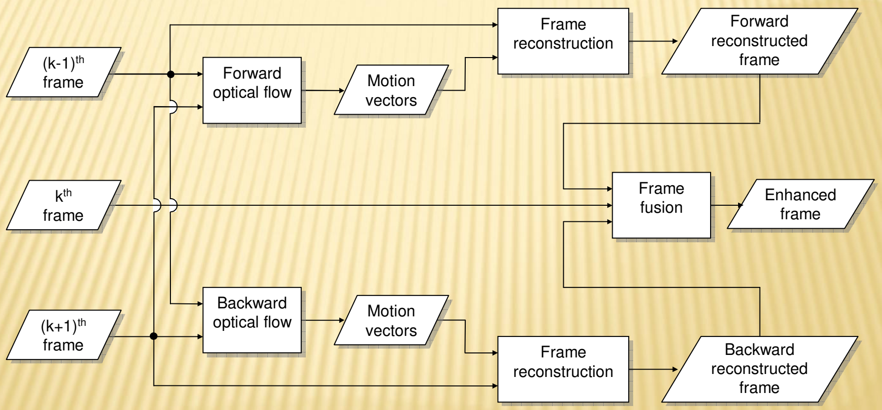
FUTURE WORKS

- 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

FLOWCHART



Thank you