






Segmentation of aortic flow in real-time magnetic resonance images


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Making excuses




- Presenting on behalf of Gustavo Mendonça
 - Undergraduate student, Scientific Initiation Program
 - Could not be here
- Forgot adapter plug! 
 - Slide preparation time \leq notebook battery life



Motivation

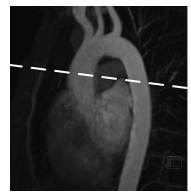

- Autonomic control over cardiovascular system:
 - Heart rate variability (HRV)
 - Blood pressure variability
 - Venous return variability
 - Stroke volume variability (SVV)
- No gold standard for SVV measurement
- MRI has potential for non-invasive SVV measurement (Carvalho *et al.*, ISMRM 2007 & 2008)



MRI measurement of SVV

Carvalho *et al.*, ISMRM 2007 & 2008

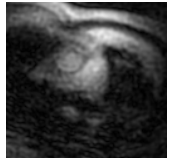

- Slice prescription: ascending aorta
 - Anterior to main bifurcations
- Phase contrast MRI
 - Measures blood velocity through imaging plane
- Requires precise segmentation of aortic flow

Real-time MRI

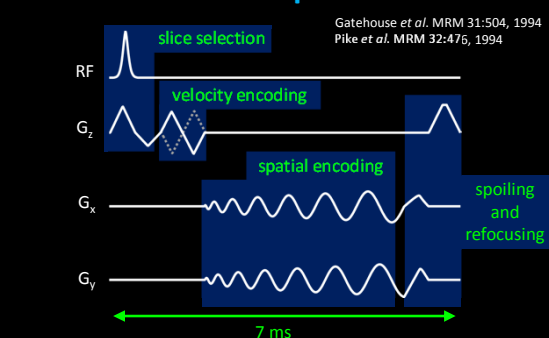
- Pros:
 - High temporal resolution: 56 ms
 - New image every 14 ms (view sharing)
- Cons:
 - Low spatial resolution: $3 \times 3 \text{ mm}^2$
 - Low image contrast

→ Difficult segmentation

Pulse sequence

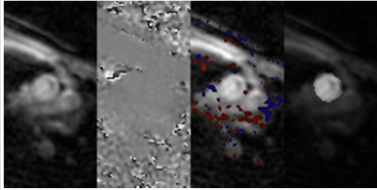
Gatehouse *et al.* MRM 31:504, 1994
Pike *et al.* MRM 32:476, 1994



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Data acquisition: real-time spiral phase-contrast MRI

- Each morphological maps is associated to a velocity map

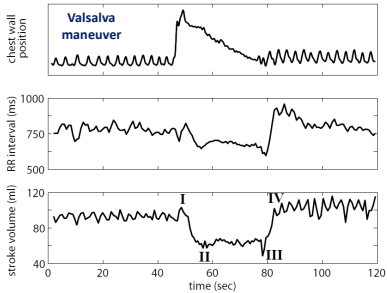


- Data acquired at 3T
- Spatial res.: $3 \times 3 \text{ mm}^2$
- Temporal res.: 56 ms
- View-sharing: new image every 14 ms
- Vel. range: $\pm 200 \text{ cm/s}$

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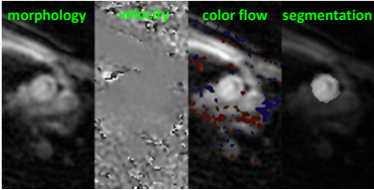
MRI measurement of SVV

Carvalho et al., ISMRM 2007 & 2008



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Limitations



- Previous implementation:
 - Inaccurate segmentation
- Does not adjust to aortic motion/pulsation
- This work: improves segmentation

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Proposed algorithm

Parameter initialization

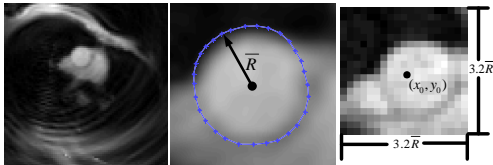
- One time only; graphical interface

- Finding the center of the aorta
 - Before segmentation of each frame
 - Fully automatic, iterative
- Image segmentation
 - Needs to know where the center of the aorta is

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Initialization: restricting search region

- Large enough to contain aorta during entire acquisition
- Calculated from manually-prescribed radius (1st frame only)

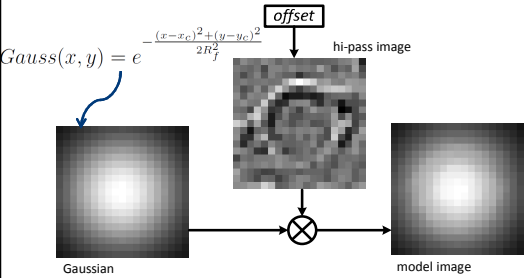


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Segmentation: model image construction

$$Gauss(x, y) = e^{-\frac{(x-x_c)^2 + (y-y_c)^2}{2R^2}}$$

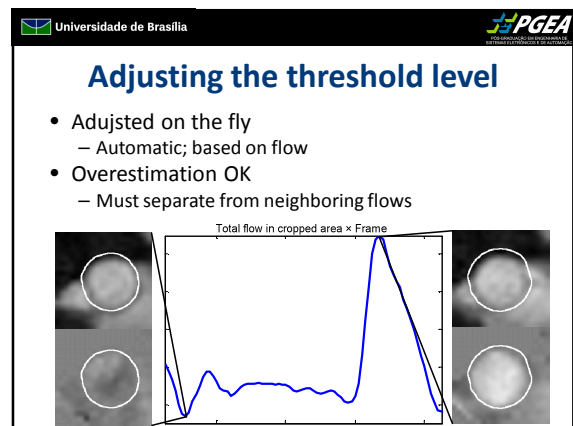
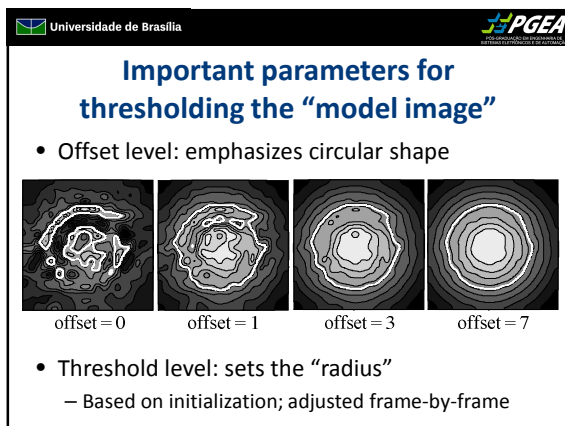
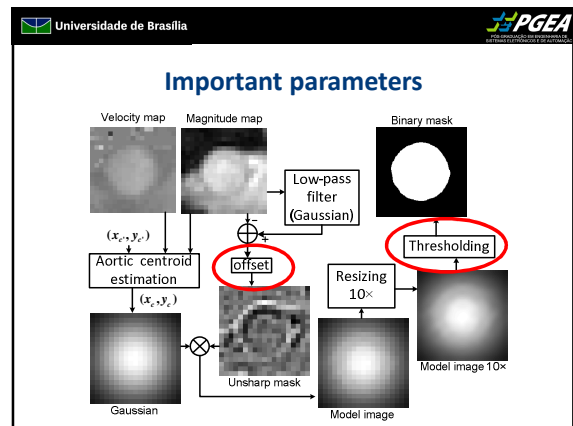
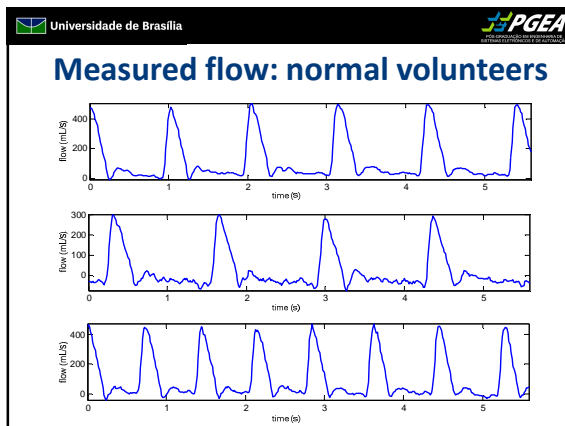
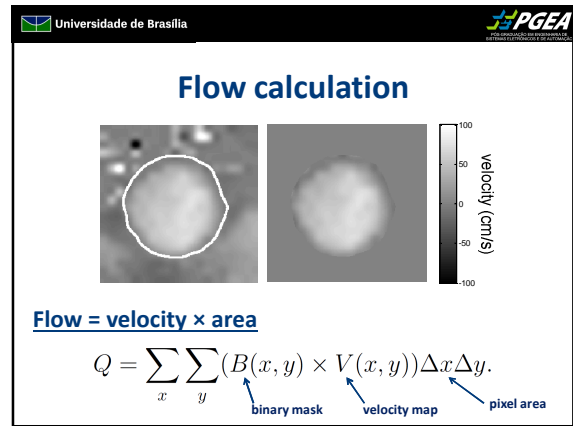
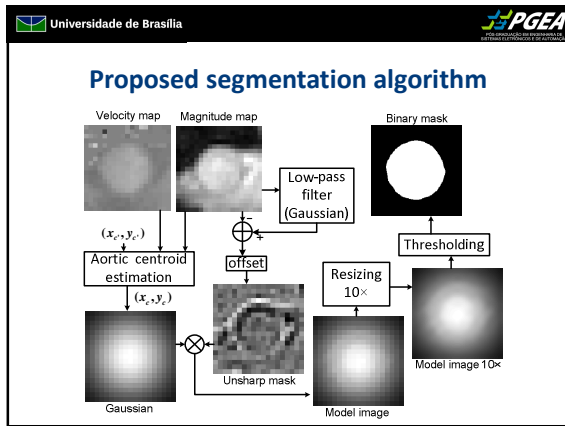
offset

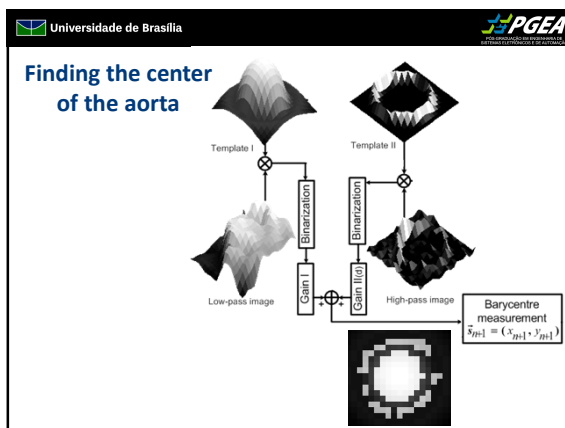
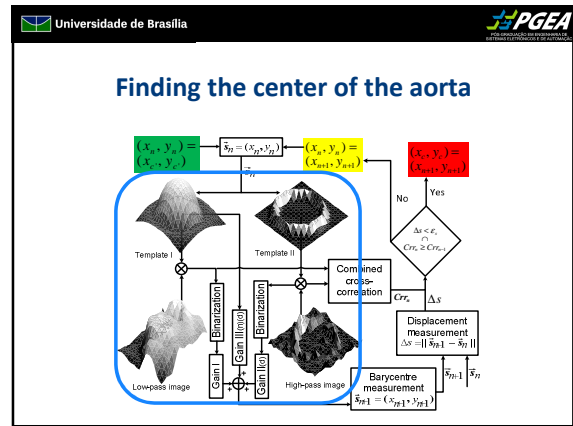
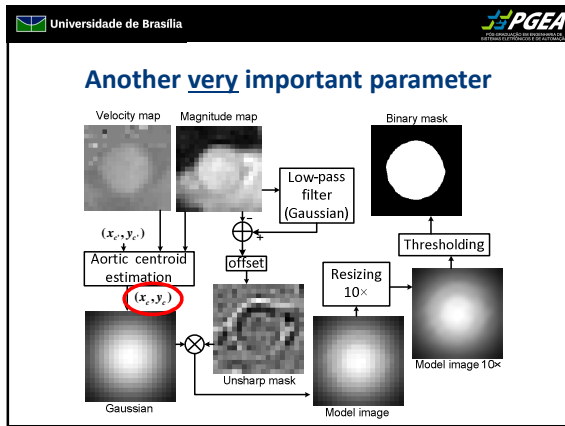


hi-pass image

Gaussian

model image





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Finding the center of the aorta: iterative process

- Template I and Template II:
 - Shifted to current center
 - Multiplied with low- and hi-pass images
- Barycenter is measured → new center

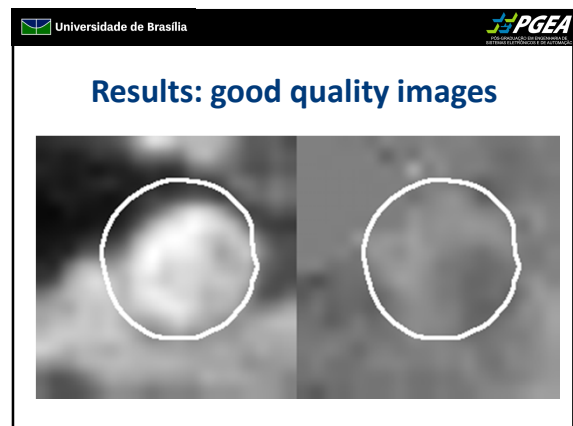
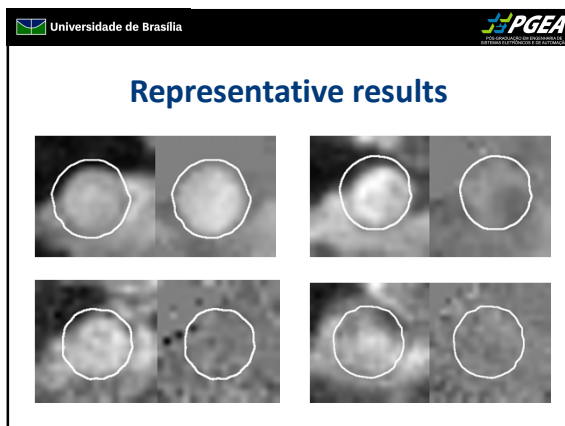
i) $Crr = 0.439$
 $\Delta s = 1.22$

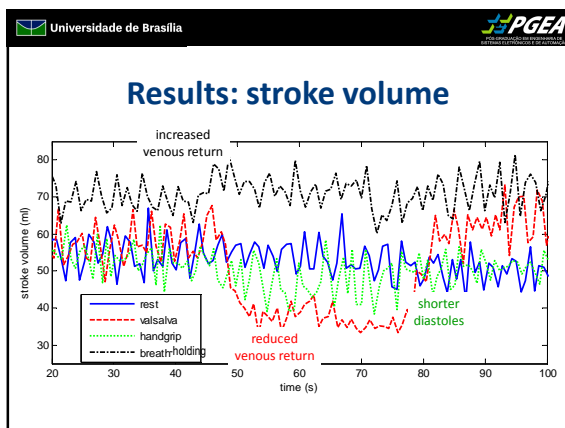
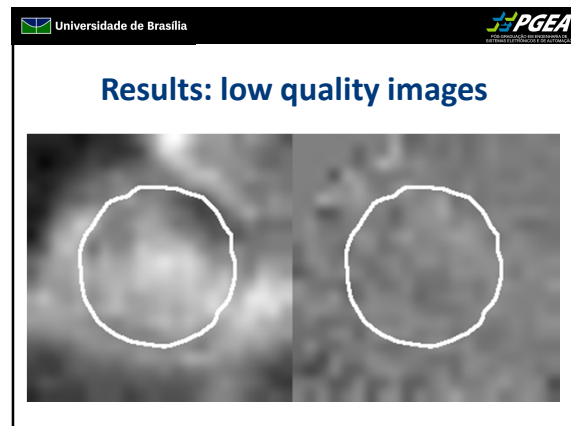
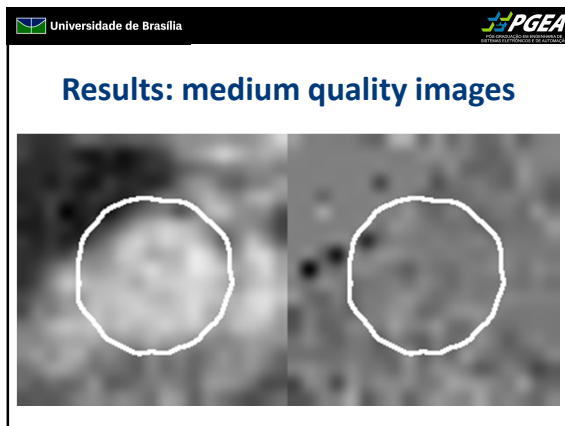
iv) $Crr = 0.739$
 $\Delta s = 0.44$

vii) $Crr = 1.15$
 $\Delta s = 0.86$

x) $Crr = 1$
 $\Delta s = 0.04$

- Process ends when: shift $\leq 5\%$ of radius





Discussion

- Flow is lower near vessel wall

- If center is incorrect by 10% of the radius:
→ flow incorrect by 4%
- If threshold is incorrect by 10% of the radius:
→ ditto
(better to overestimate than to underestimate)

Conclusions

- Proposed algorithm
 - Model-based approach: segments a Gaussian-like image
 - Attempts to separate the flow, not to segment the lumen
- Tracking and segmentation seems visually good
 - Considerably improved over our first attempts
 - Next: comparison with segmentation by specialists
- Demonstrated beat-by-beat stroke volume measurement
- Real-time MRI has strong potential for non-invasive measurement of SVV

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PGSIM
 Grupo de Processamento de Sinais e Imagens Médicas

Obrigado
 Thank you
 ありがとう

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