Motion correction for accurate interpretation of parametric images

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Outline

1. Motion correction: few thoughts

2. Dealing with motion in parametric imaging

   - Detecting and rejecting motion-corrupted images
     - ASL imaging of the thigh
     - Contrast ultrasound in mice

   - Motion correction
     - Cardiac MR
     - Echocardiography

Motion correction (and registration): 3 key choices

1. Type of deformation between the datasets:
   - rigid, affine, elastic (deformation field)
   depends on the expected deformation

2. Reference to register frames with
   - all registration methods are not symmetrical
   highly depends on the context

3. Criterion to measure the quality of registration
   - mutual information, correlation, ratio of variance, absolute difference, squared difference, aso
   depends on the type of similarity between images

4. Software that does the job: AIR, Pixies, aso

Motion correction (and registration) in a specific context

The best strategy for correction or registration highly depends on the context

A strategy developed in a context will almost never be appropriate without any change in a different context

The best one should probably aim at:

- better understanding the concepts
- knowing who knows how to do what
- knowing the available tools
- sharing experience and possibly tools

Dealing with motion in parametric imaging

Two approaches:

- Detecting and rejecting the images corrupted by motion
  Loss of sensitivity, but can be appropriate when sensitivity is not a problem (trade-off between kinetic blur and sensitivity)

- Compensating for motion

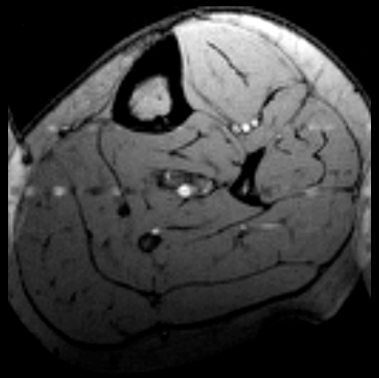
Detecting and rejecting images corrupted by motion

- Arterial Spin Labeling of the thigh for studying muscular perfusion

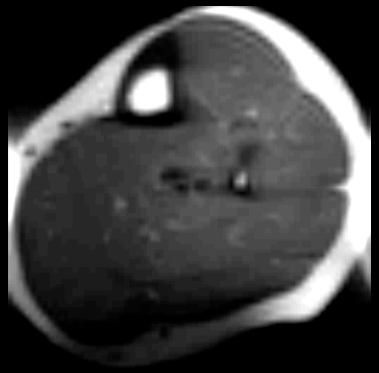
- Contrast ultrasound in mice and human studies

Detecting and rejecting images corrupted by motion: example in ASL

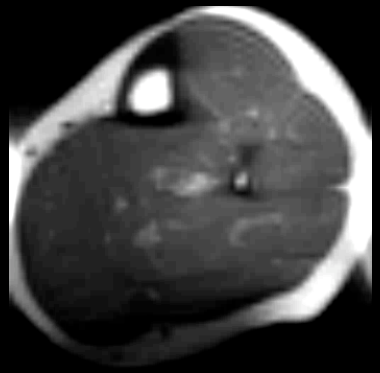
Characterization of the muscle perfusion in the thigh using ASL



anatomy (gradient echo)



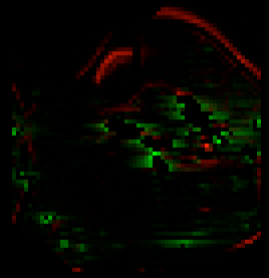
tagged



untagged

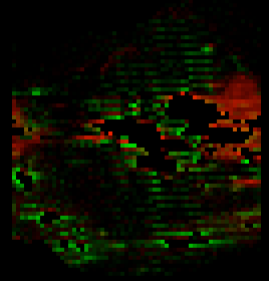
Impact of rejecting spurious images on parametric images

Using all images of the time series



High
Medium
Low

After rejection of spurious images

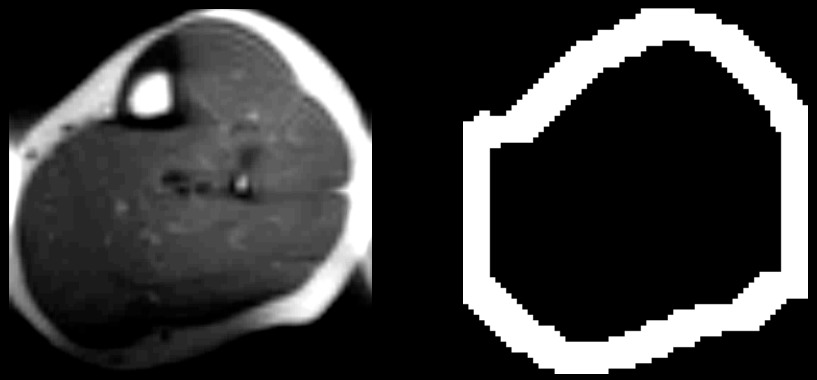


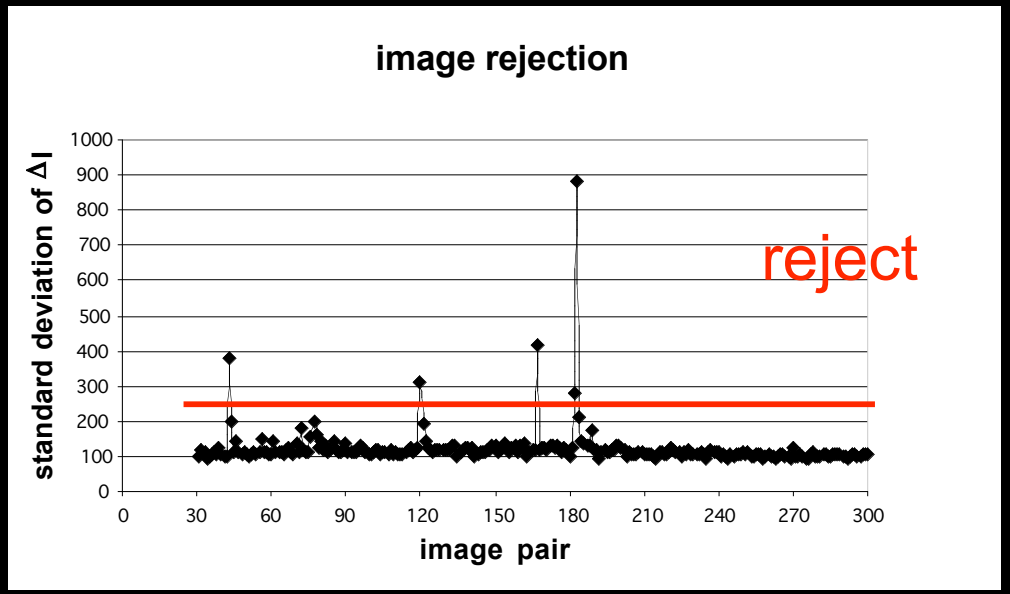
Parametric images

Perfusion maps

Method for detecting motion

Detection of the variation in signal intensity between pairs of images in a well chosen region



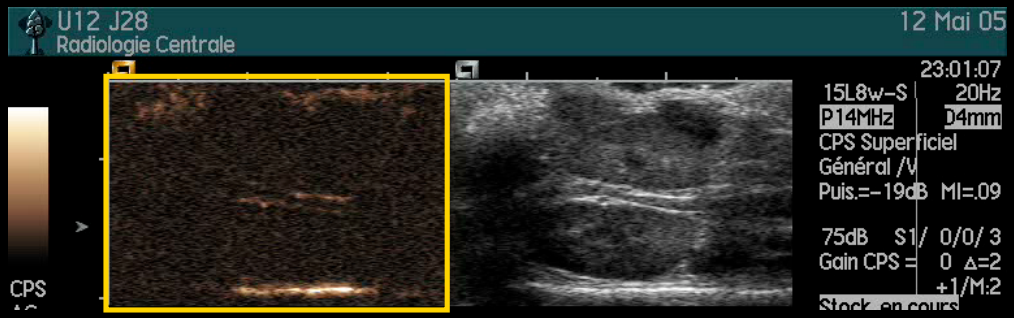


Very simple but great impact on parametric images

Frouin et al, Magn Reson Imaging, in press

Detecting and rejecting images corrupted by motion: example in CU

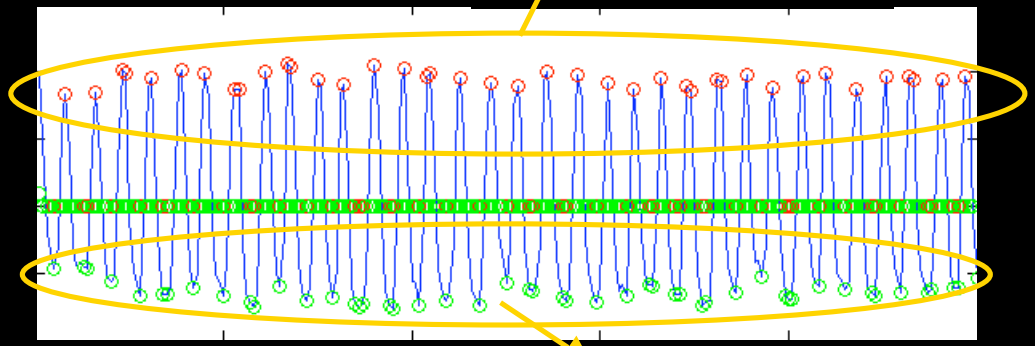
Contrast ultrasound in mouse kidneys



CPS sequence

25 Hz over 20s

Subset of frames corresponding to maxima of the respiratory cycle

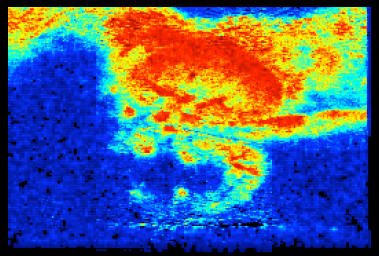


Subset of frames corresponding to minima of the respiratory cycle

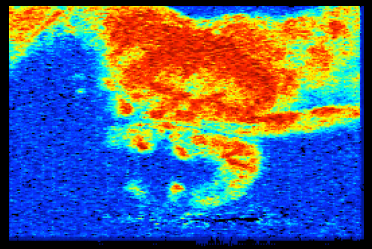
Renault et al., Phys Med Biol, 2005

Impact on parametric images

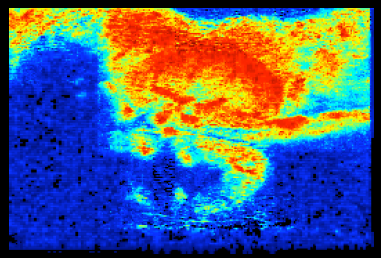
Planes corresponding to maxima



No gating



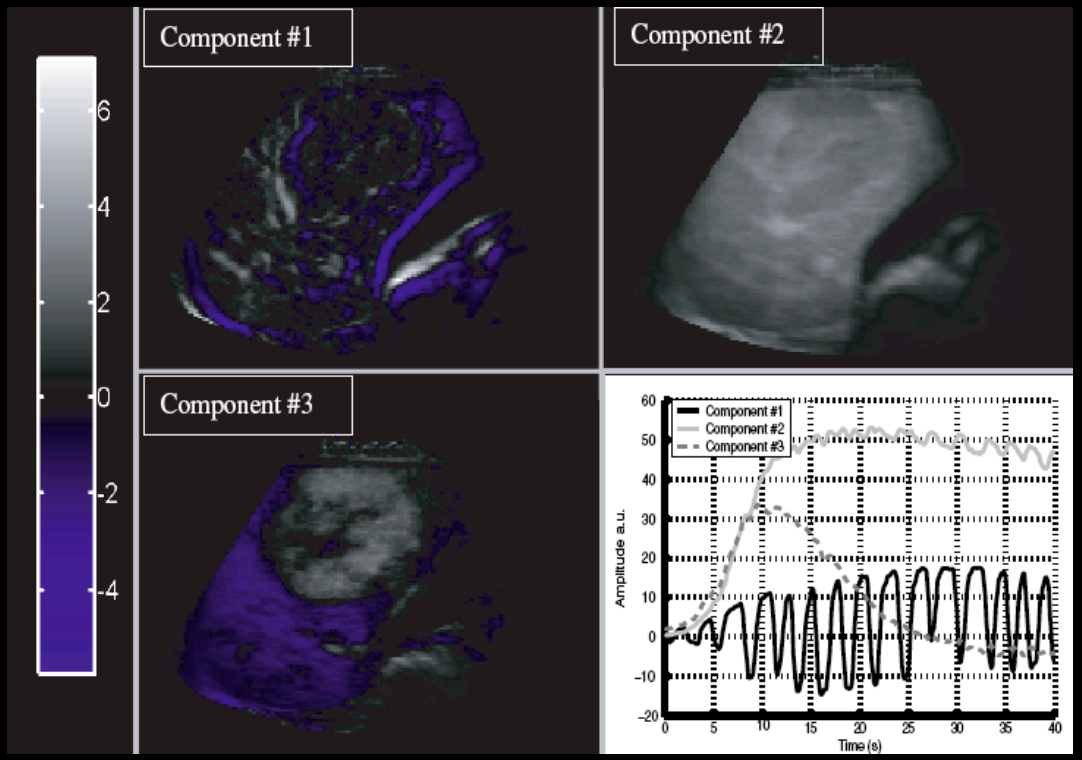
Planes corresponding to minima



Renault et al., RSNA 2005

Method for detecting motion

- Independent Component Analysis of the image sequence S(p,t) (p: pixel, t: time)
- Selection of the component with oscillations close to a respiratory component: a posteriori gating



liver patient' study

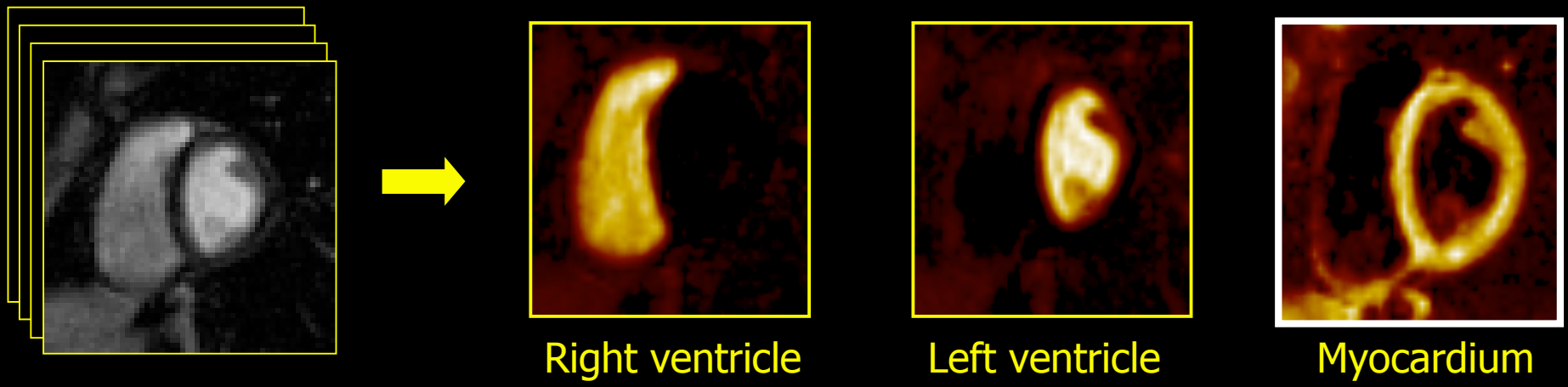
Renault et al., Phys Med Biol, 2005

Compensating for motion

- Cardiac MR for studying myocardial perfusion
- Echocardiography

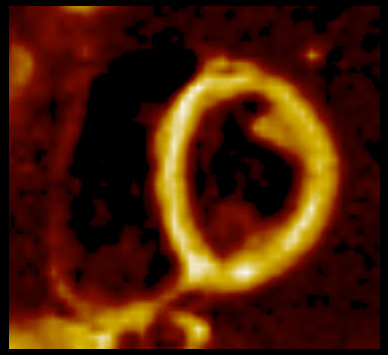
Parametric imaging in cardiac perfusion MR

FLASH sequence (TR=6.5 ms, TE = 3 ms, TI = 300 ms, flip angle : 11°) with Gd-DTPA-BMA

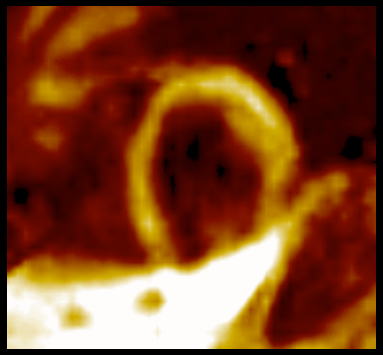


Impact of motion on myocardial images

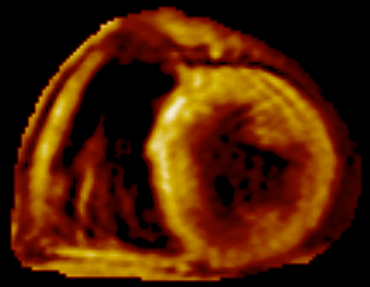
Normal volunteer holding breath



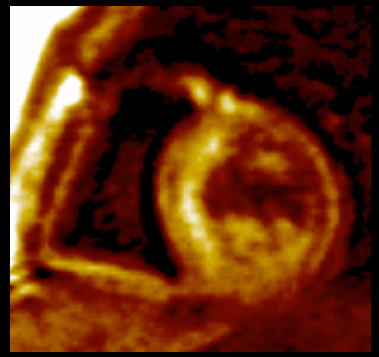
Normal volunteer with normal breathing



Patient holding breath

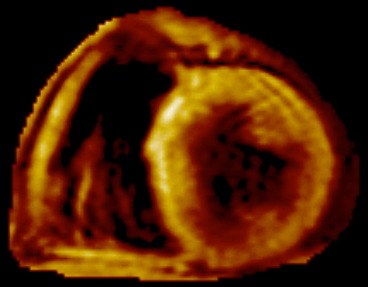


Patient with normal breathing

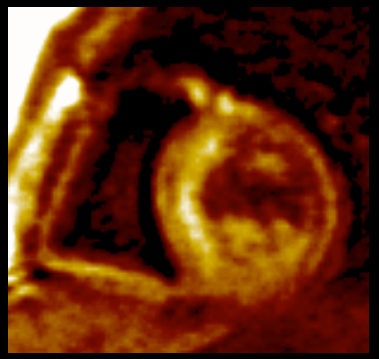


Impact of registration

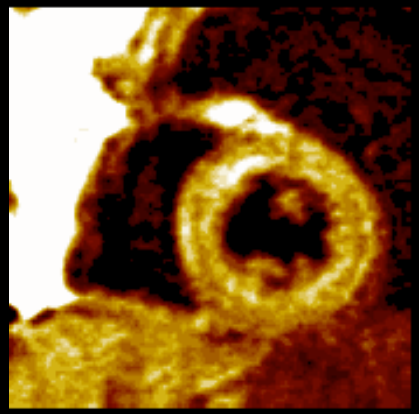
Patient holding breath



Patient with normal breathing

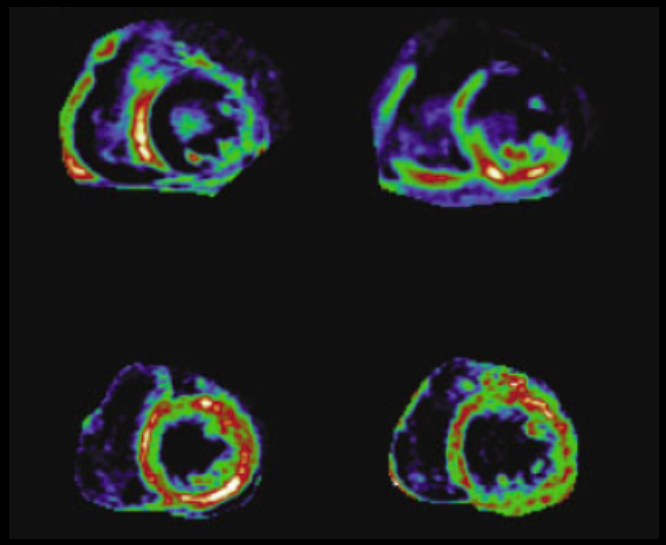


After motion correction



Other examples

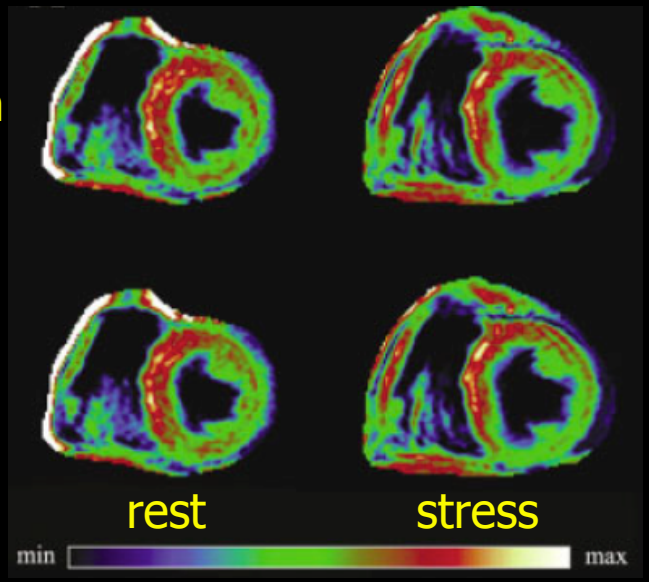
Great motion artefacts

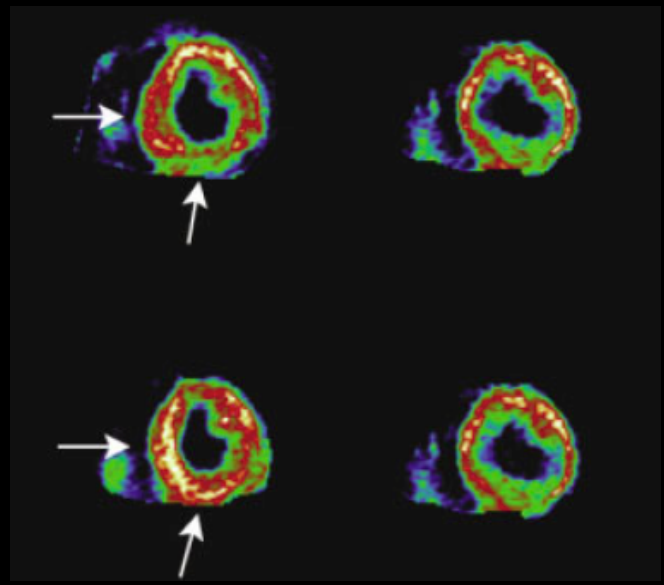


Almost no motion artefact

no correction

corrected

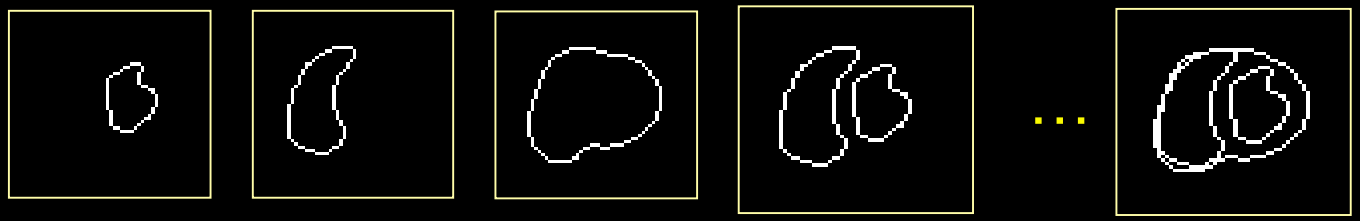




Delzescaux et al., JMRI, 2003

How was motion compensated for?

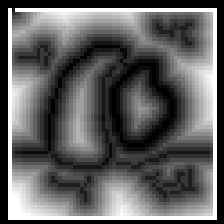
- Definition of 7 shape-based models: RV, LV, pericardium, RV+LV, RV+pericardium, LV+pericardium, LV+RV+pericardium



- For each image of the series, selection of the optimal model using a superimposition score between the transformed image and each possible model

- Geometric transformation: 2D x and y translations

- Registration criterion: based on a potential map of the image being registered

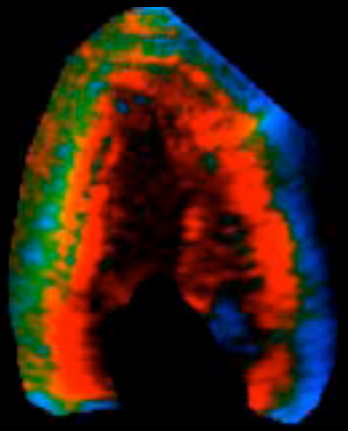


Delzescaux et al., Magma, 2001

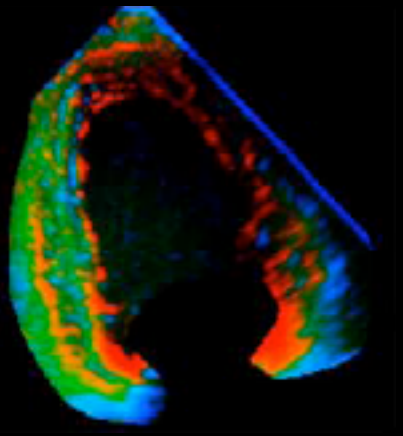
Parametric imaging in echocardiography

Standard echocardiography protocol in harmonic mode

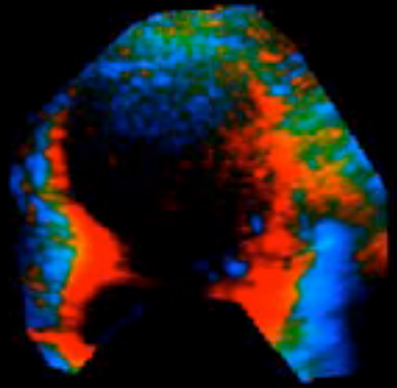
Contraction-relaxation in red
Constant in green
Relaxation-contraction in blue



normal



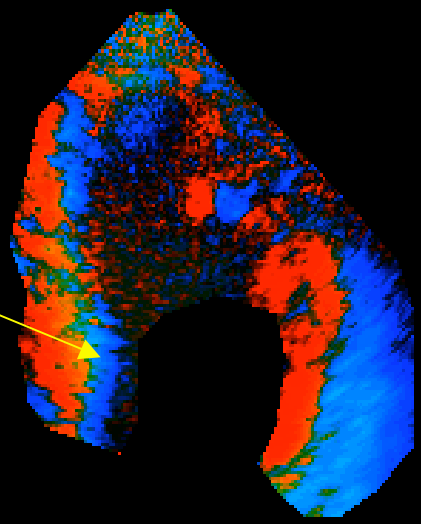
diffuse severe hypokinesia



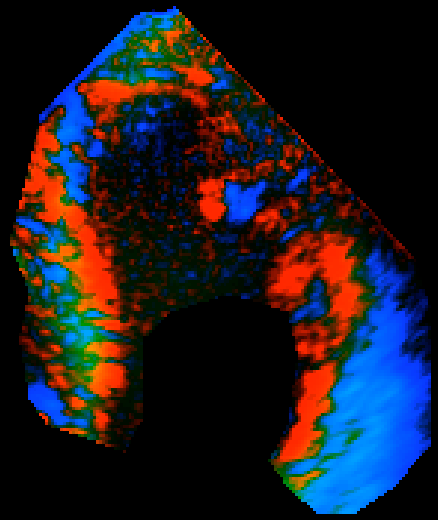
apical dyskinesia

Diebold et al., Ultrasound Med Biol, in press

Impact of motion on parametric images



Without registration

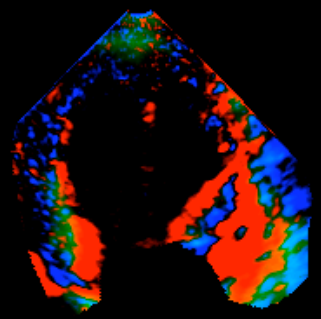


With registration

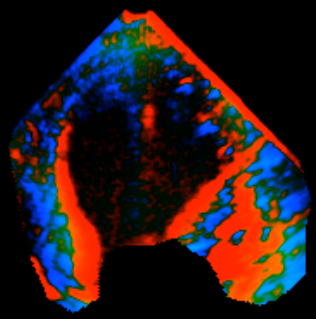
How was motion compensated for?

- 2D registration using a rigid transformation (x and y translations)
- Maximization of the cross correlation between each frame and a reference frame
- Reference frame = mid-systolic (25% of the cycle)

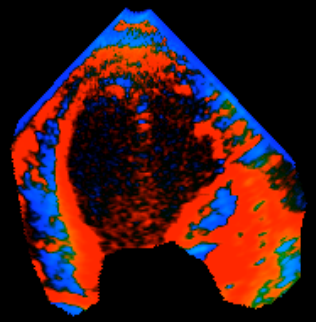
Impact of the reference frame



mid-systolic



diastolic



previous frame

Conclusions

- Motion might result in qualitative and quantitative misinterpretation of parametric images
- Just rejecting motion-corrupted frames can be a first useful step towards better interpretation
- Designing a motion correction scheme is extremely dependent on the application
- Many tools do exist and can be helpful after specific tuning for a specific problem