A NOVEL METHOD FOR MOTION CORRECTION IN CARDIAC MRI

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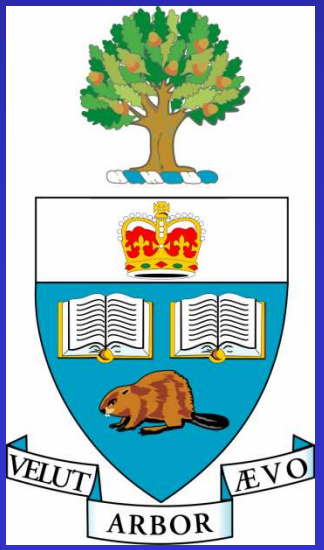
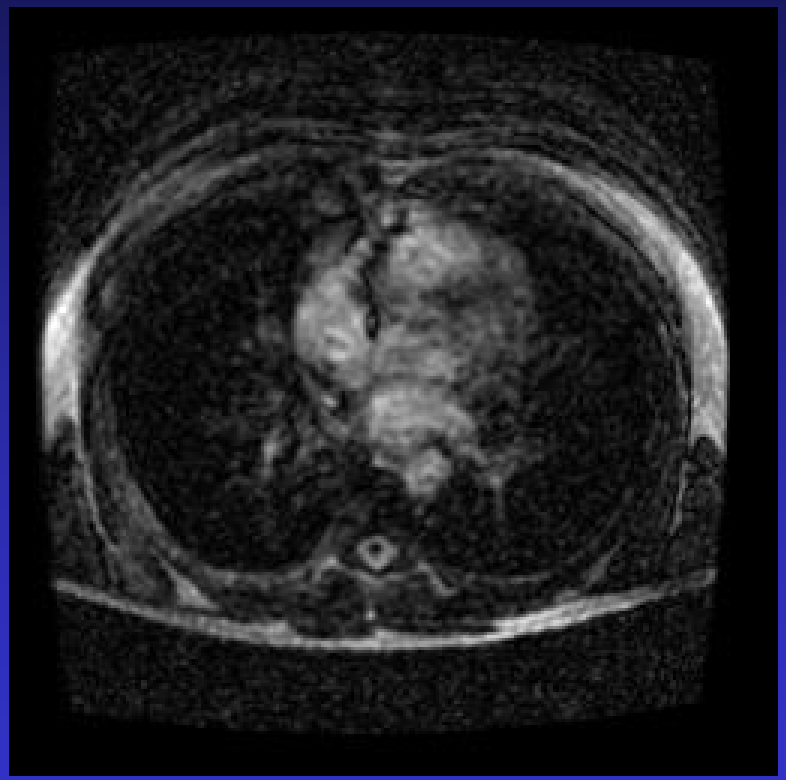
MITACS-Fields Conference on the
Mathematics of Medical Imaging
June 21, 2011

University Health Network



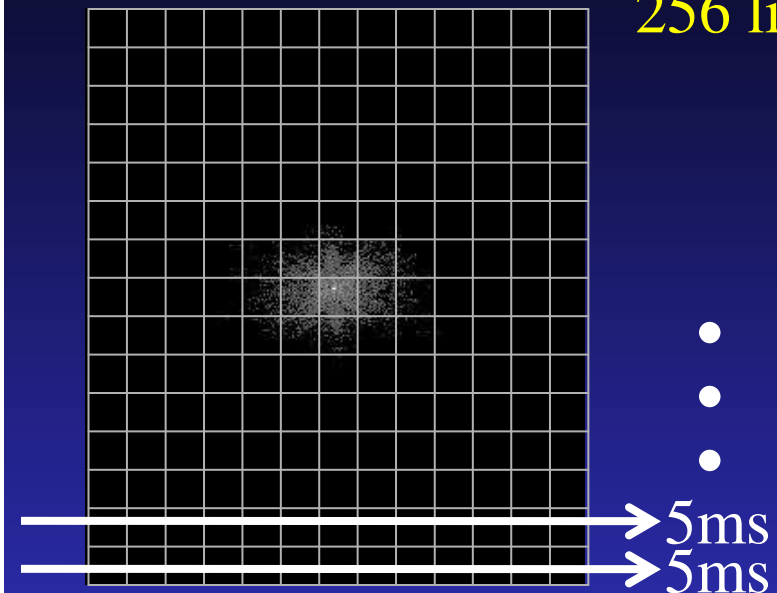


OUTLINE

- Basic MR image formation
  - Motion–related errors
- Motion compensation methods
  - Challenge:
    - § Complex cardiac motion
    - § Limited information about that motion
  - New method

MR IMAGE FORMATION

256 lines: ~ 1 second



Fourier-Space

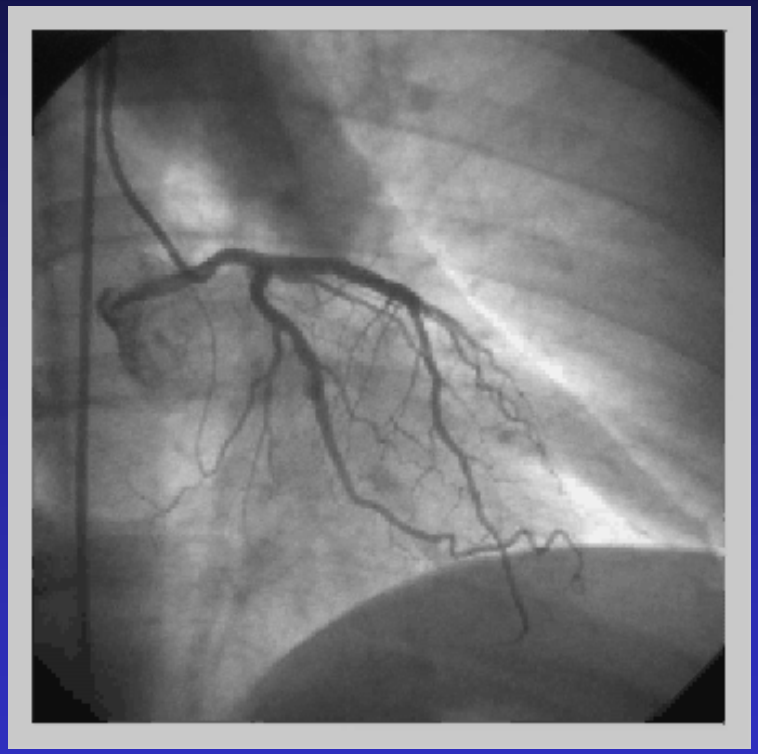
- Multiple slices: ~ minute

Fourier Transform

Image

ANATOMICAL MOTION

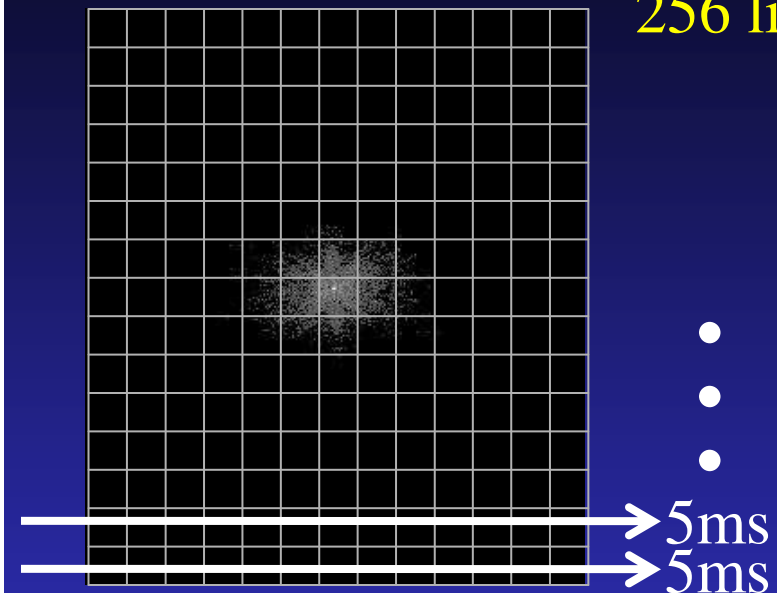
- MR scans: ~ seconds – minutes



- Motion
  - Cardiac: ~1 beat/s
  - Respiratory: ~5s per breath

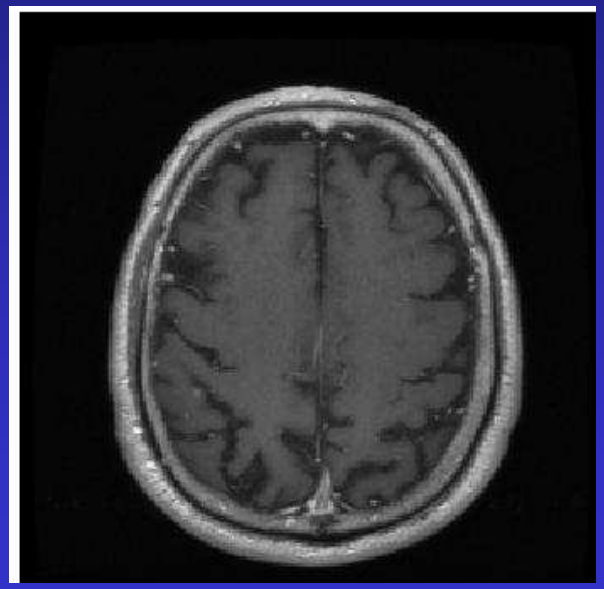
WHY IS MOTION A PROBLEM?

256 lines: ~ 1 second



Fourier Space

Fourier Transform



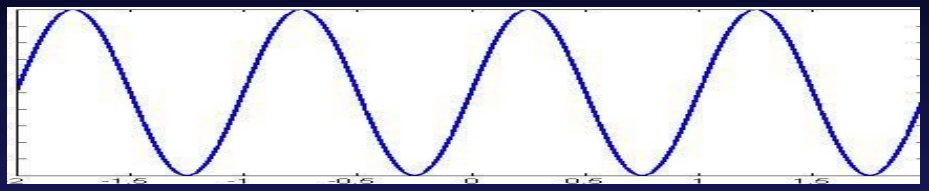
Image

- Data in different parts of Fourier space will be inconsistent

  Artifacts (errors) in the images

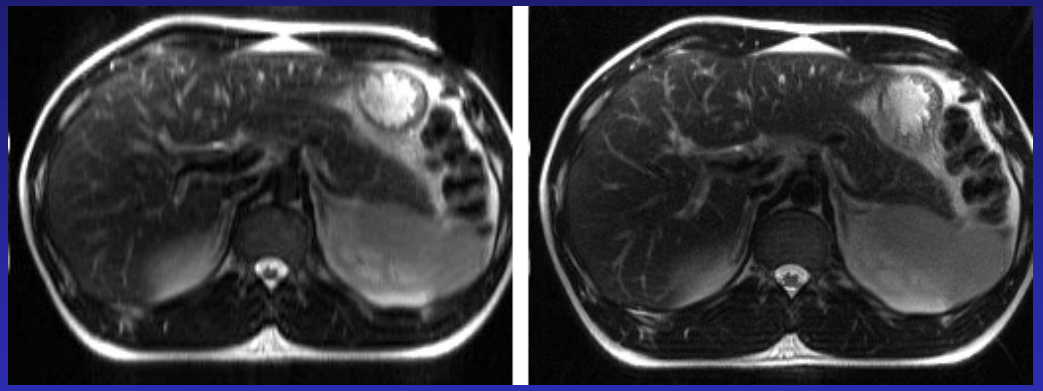
NATURE OF MRI ARTIFACTS

- Periodic motion

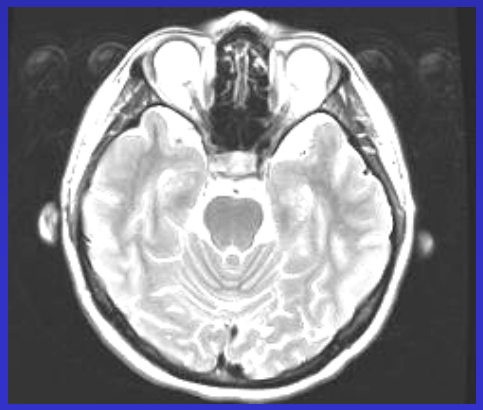


- Two types of artifacts

1) Blurring



2) Ghosting

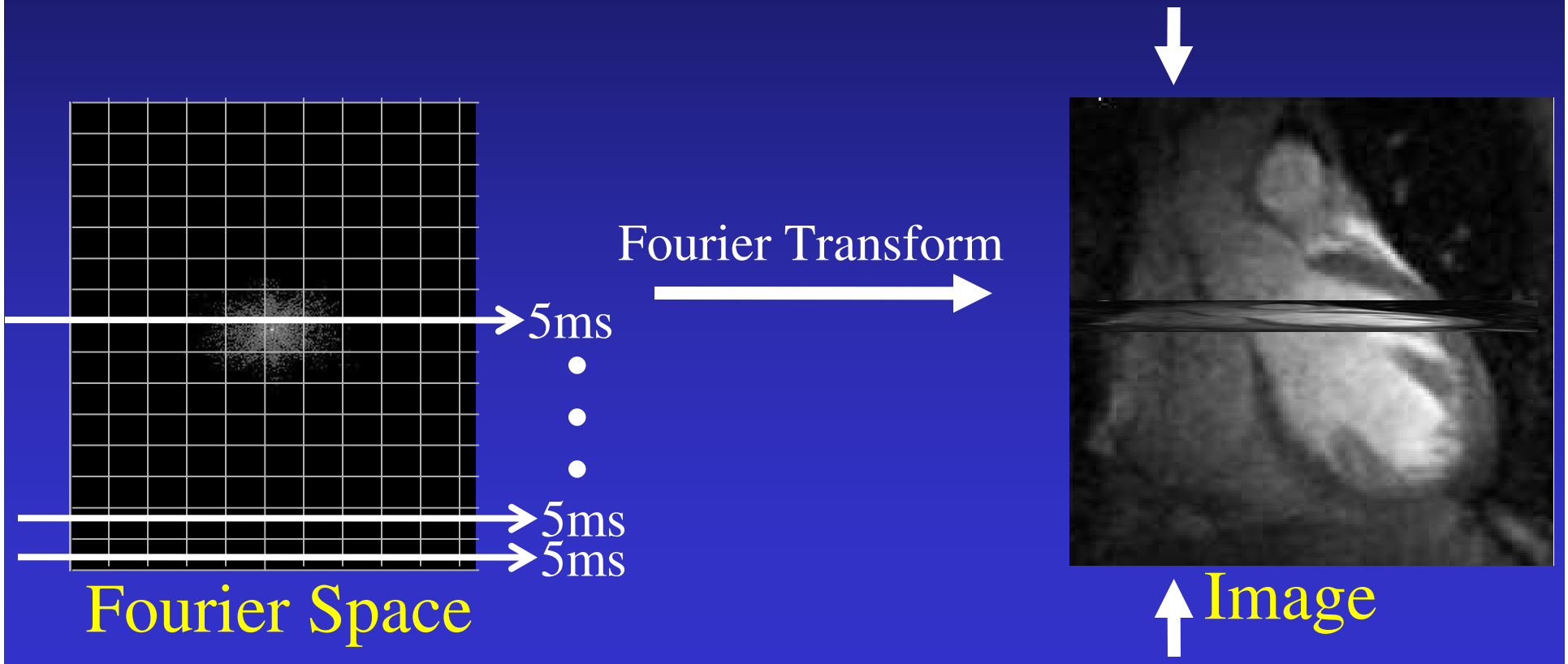


CORRECTING FOR MOTION

- Navigator echoes

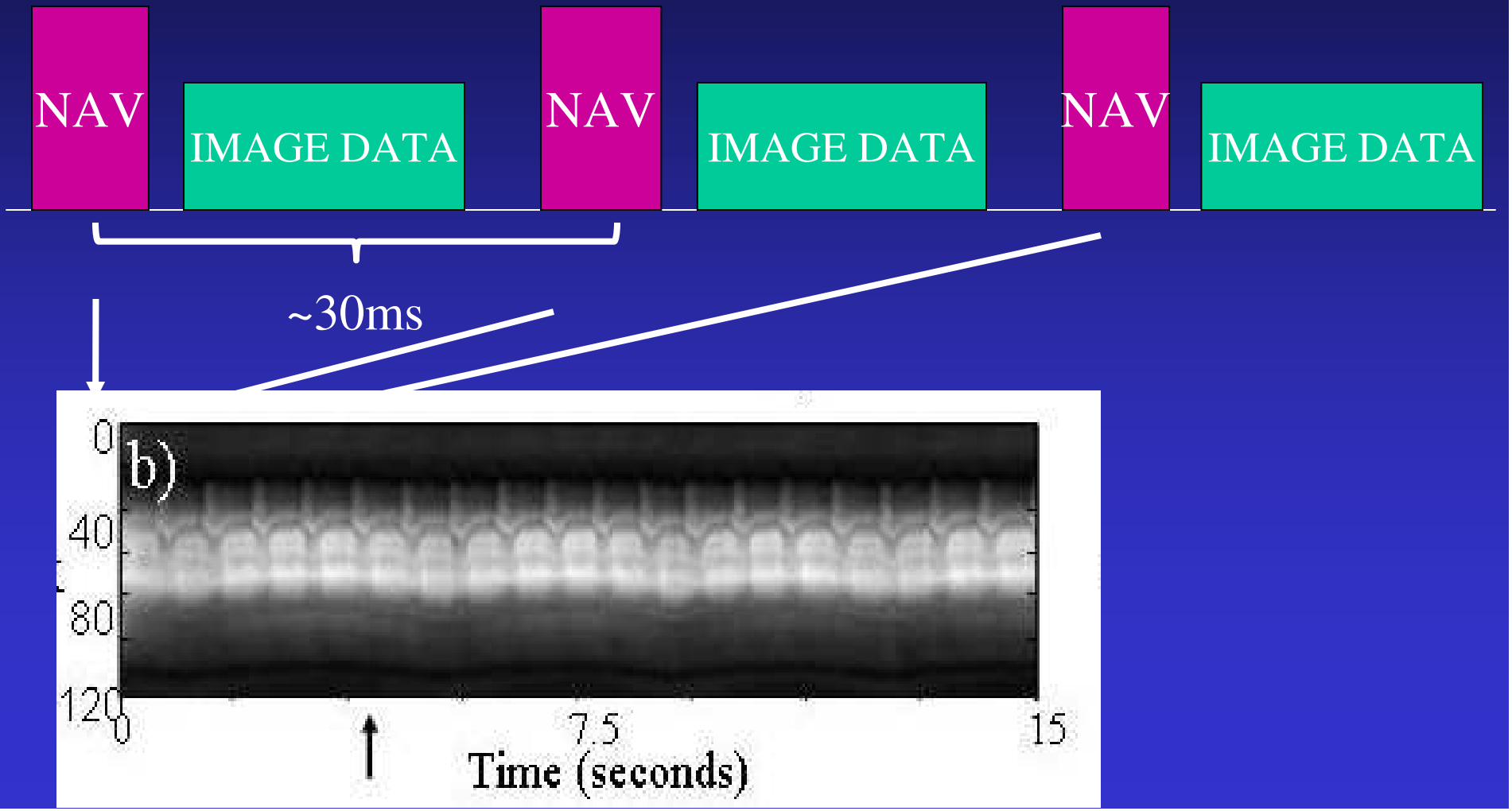
  1D Fourier Transform central line of Fourier space

  ~5ms



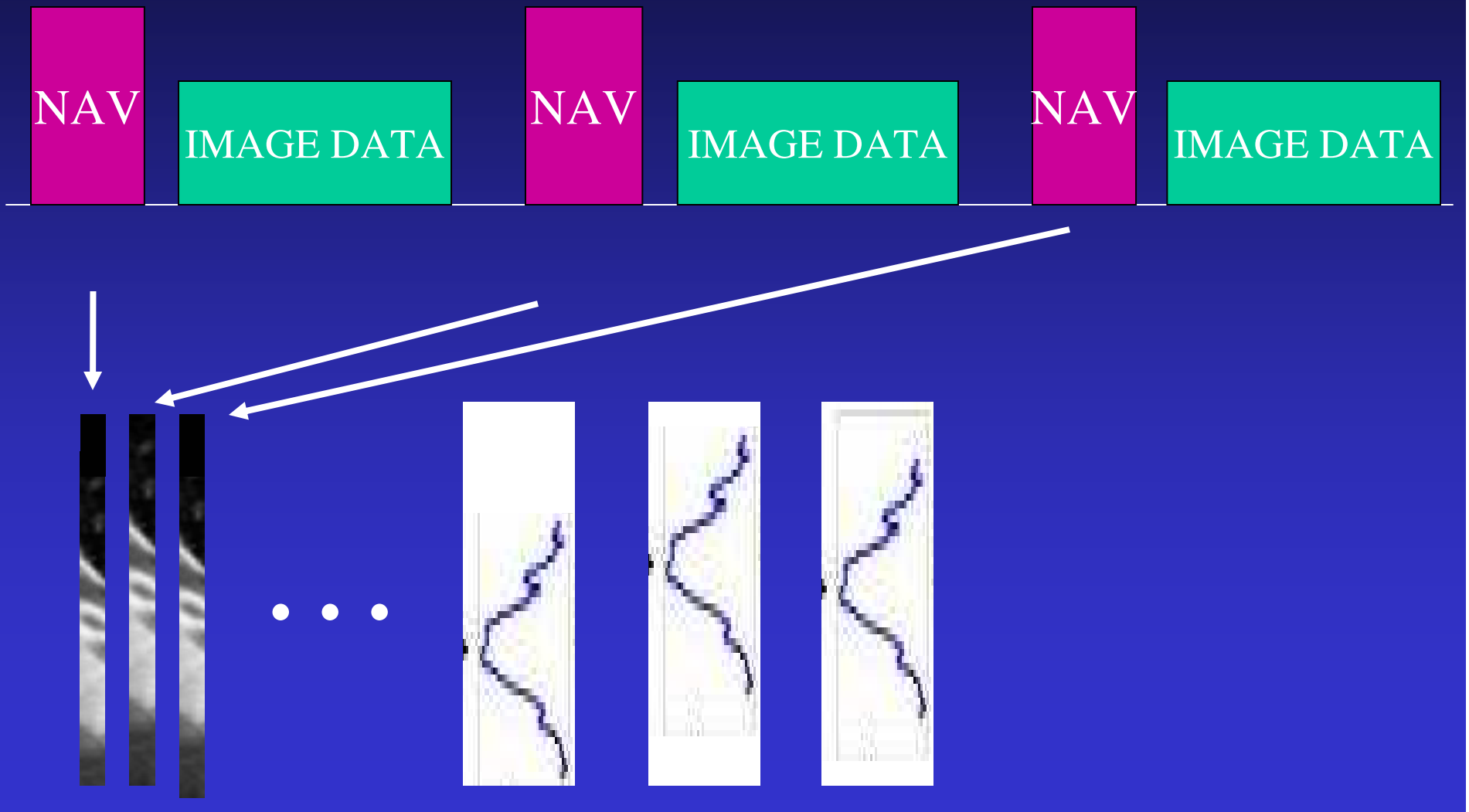
NAVIGATOR ECHOES

- Interleave navigator echo with image data acquisition
  - Obtain 1D projections every ~30ms (vs. 1 second for 2D image)
  - Use projections to monitor and correct for motion in the image data

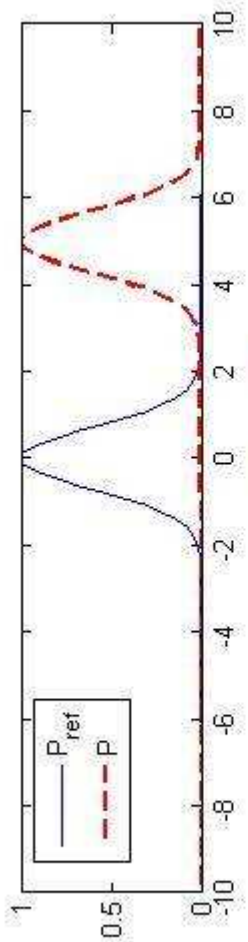


MONITORING MOTION

- To track motion, need to determine the relative displacement between 1D projections



TEMPLATE MATCHING



$$LSQ(\Delta x) = [P_{ref}(x) - P(\Delta x)]^2$$

$\Delta x = 0$, $LSQ(\Delta x) = 25$

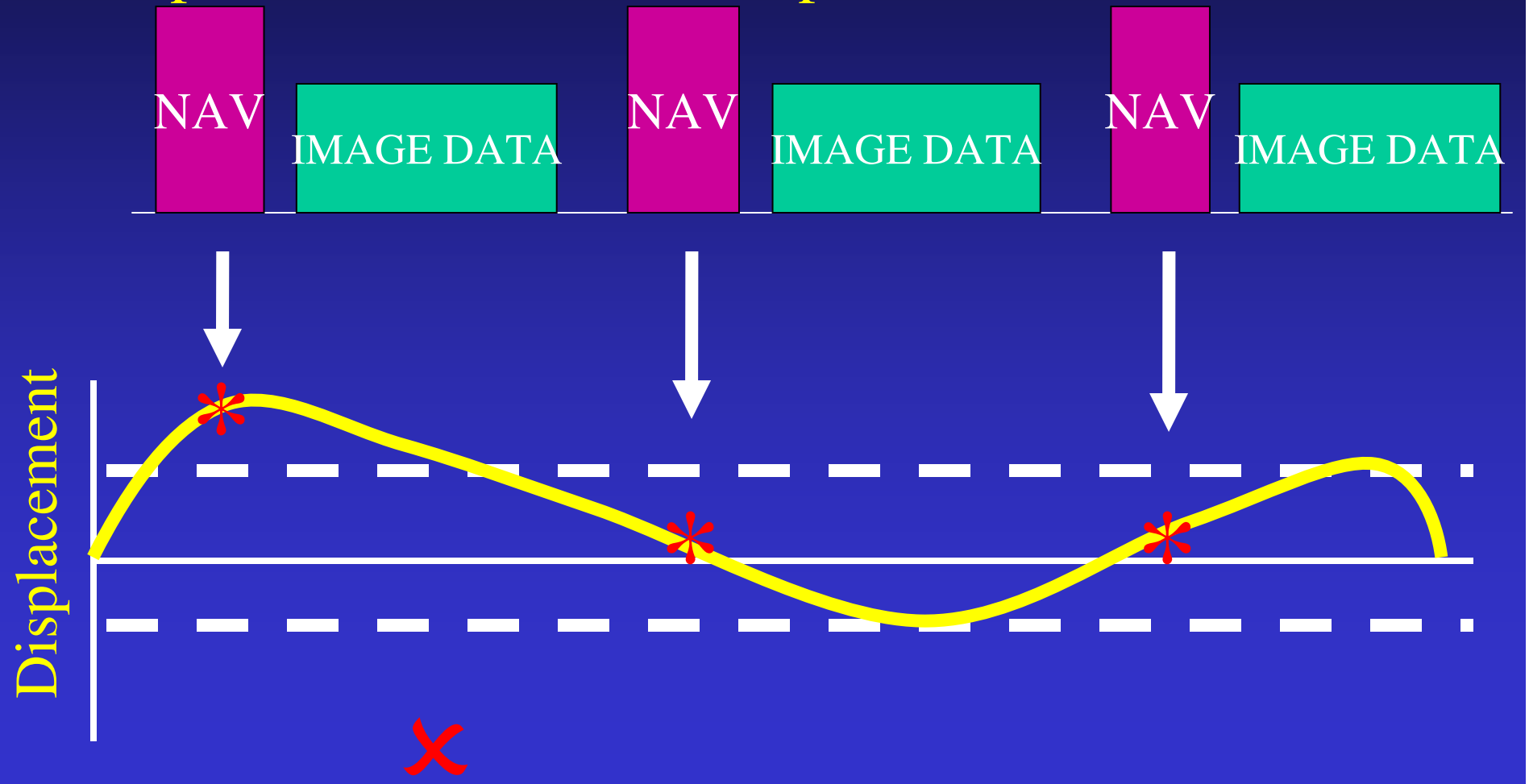
$\Delta x = 3$, $LSQ(\Delta x) = 10$

$\Delta x = 5$, $LSQ(\Delta x) = 0$

$\Rightarrow$ displacement = *5*

CORRECTING FOR MOTION

- Using template matching, can determine relative displacement of anatomy during navigator echoes
- Accept data with minimal displacement

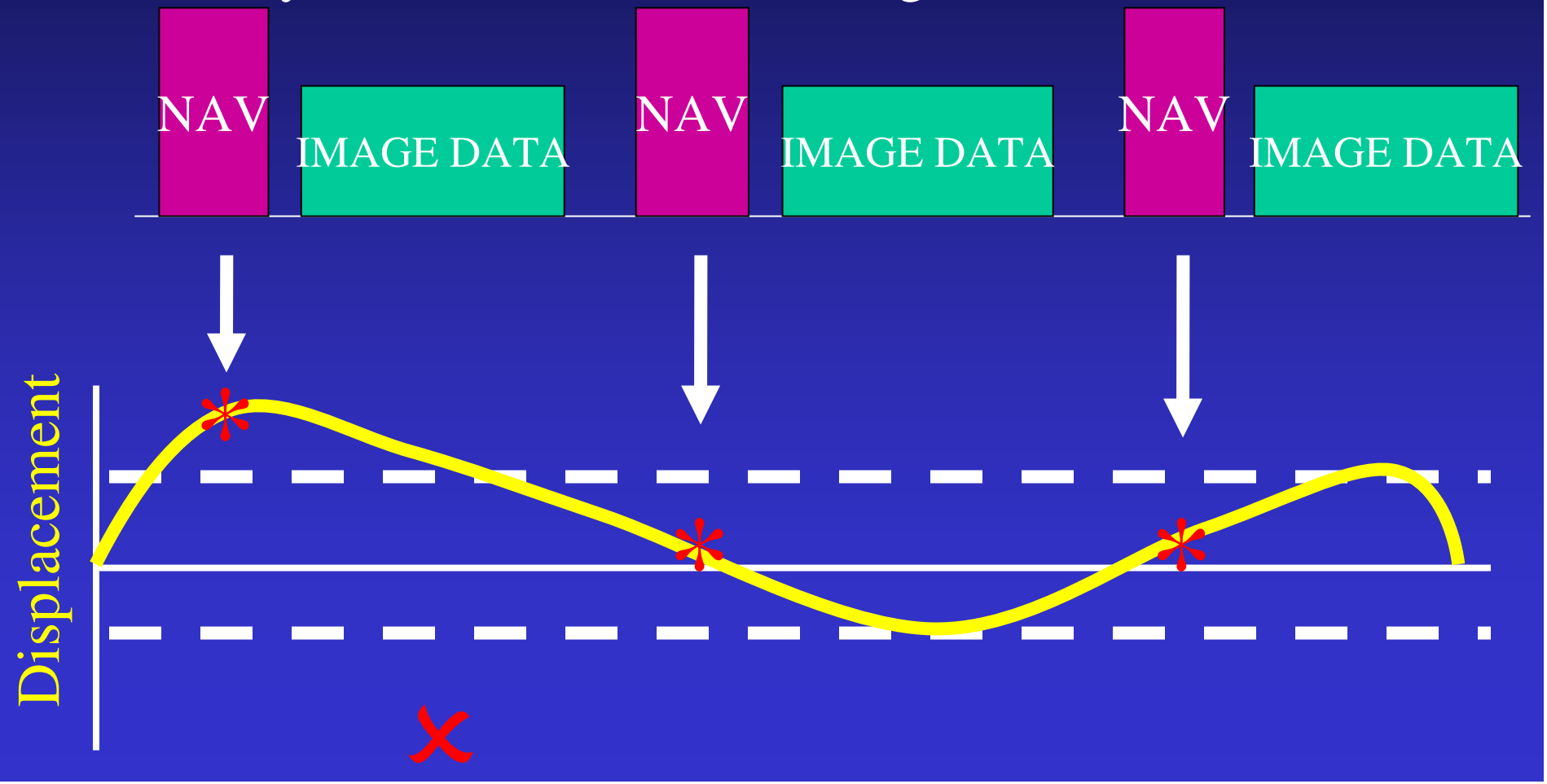


CORRECTING FOR MOTION

- Using template matching, can identify a compete set of image data with minimal relative displacement

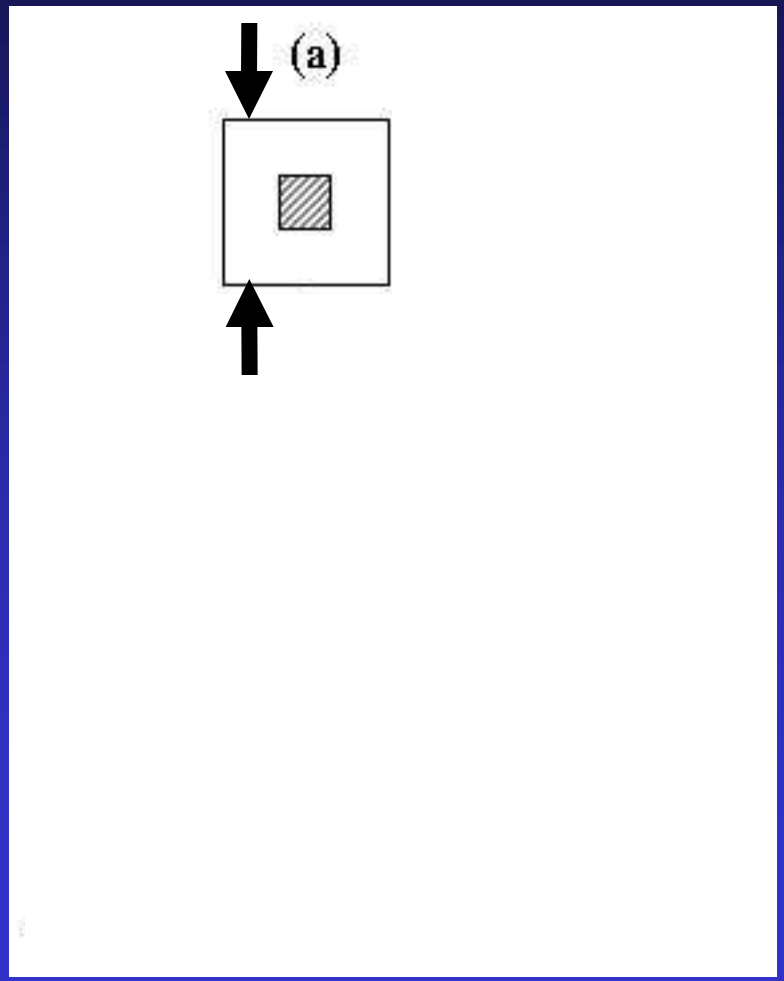
  Minimize artifacts in the image

- But: Only works if motion tracking is accurate



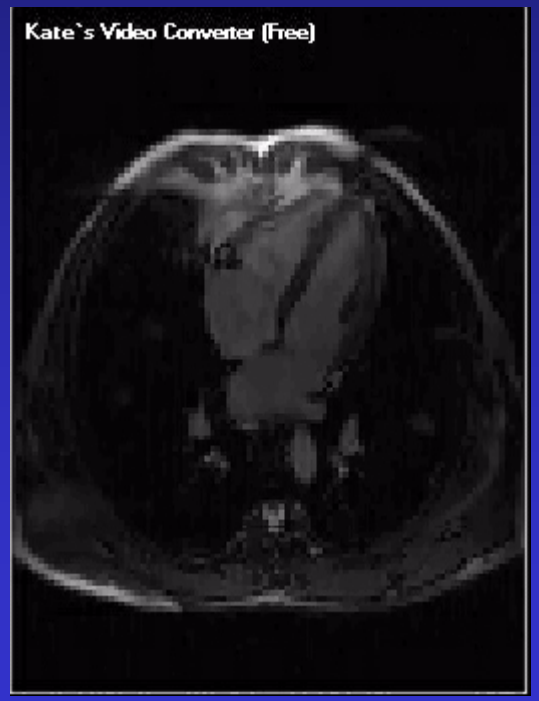
IS MOTION TRACKING ACCURATE?

- Depends on the type of motion



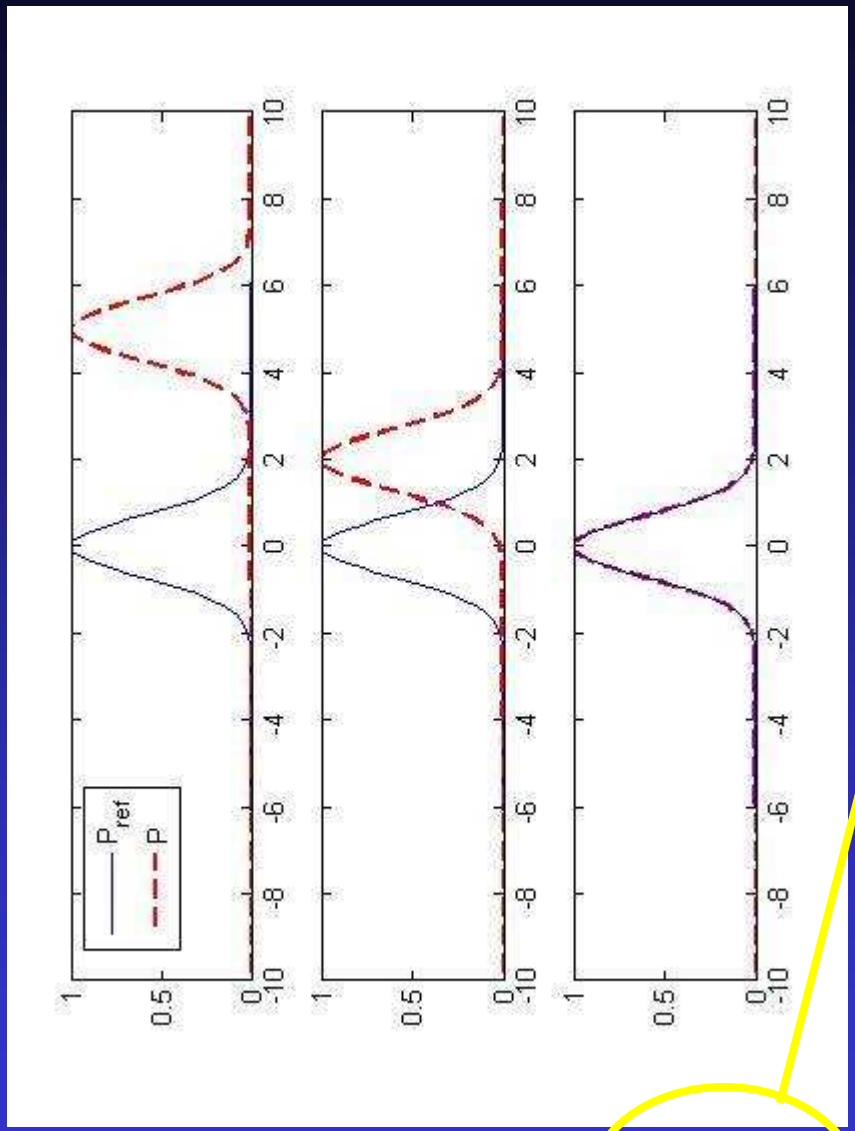
IS MOTION TRACKING ACCURATE?

- Two problems:
  1) Template matching only works well for rigid-body translation
  2) From a 1D projection, there is limited information available about the motion



Example

TEMPLATE MATCHING



$$LSQ(\Delta x) = [P_{ref}(x) - P(\Delta x)]^2$$

- This implies a rigid-body displacement of 5 pixels
- If we know the motion is rigid-body, can easily correct for it. Displacement doesn't really matter

$\Delta x = 0$, $LSQ(\Delta x) = 25$

$\Delta x = 3$, $LSQ(\Delta x) = 10$

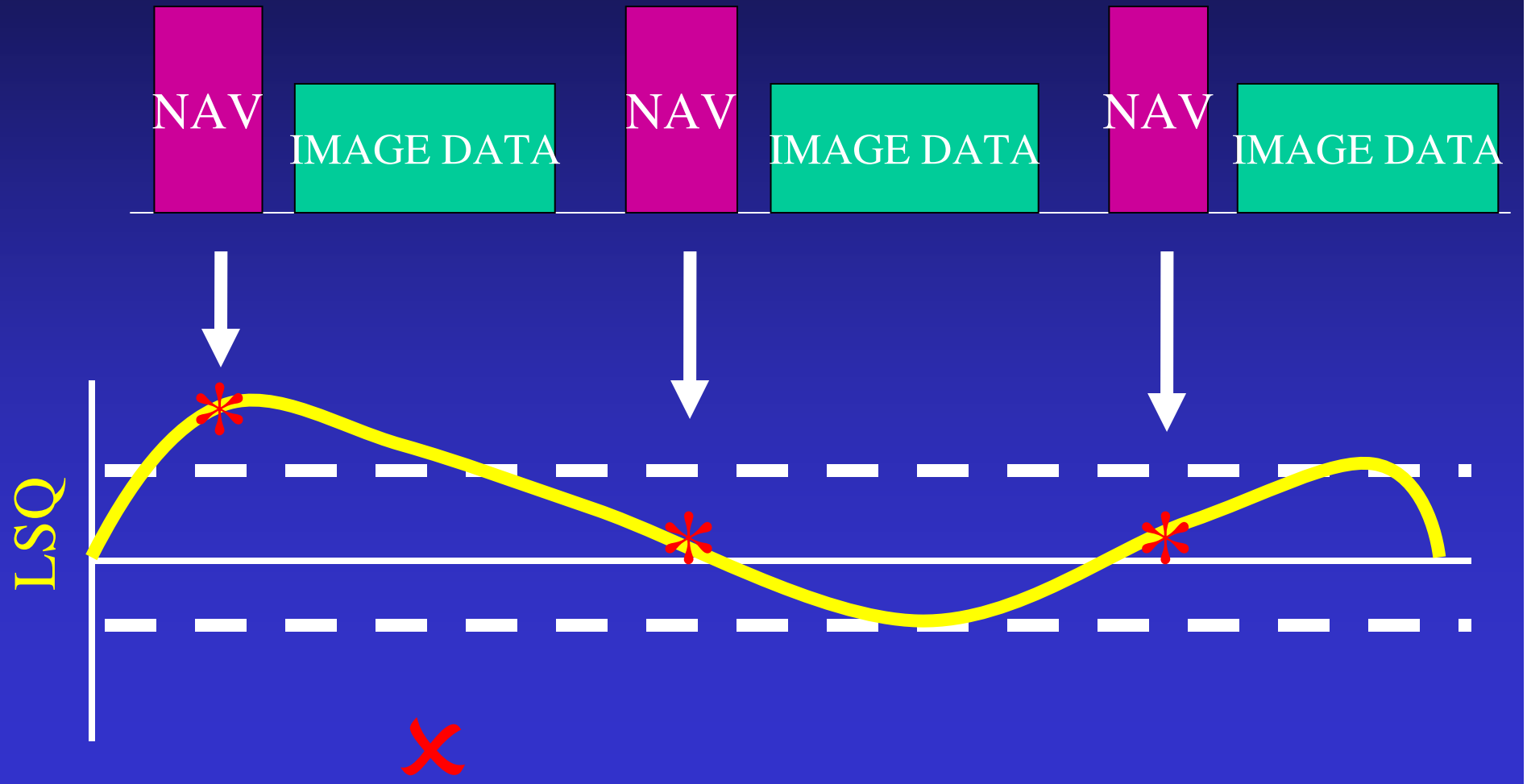
$\Delta x = 5$, $LSQ(\Delta x) = 0$

$\Rightarrow$ displacement = 5

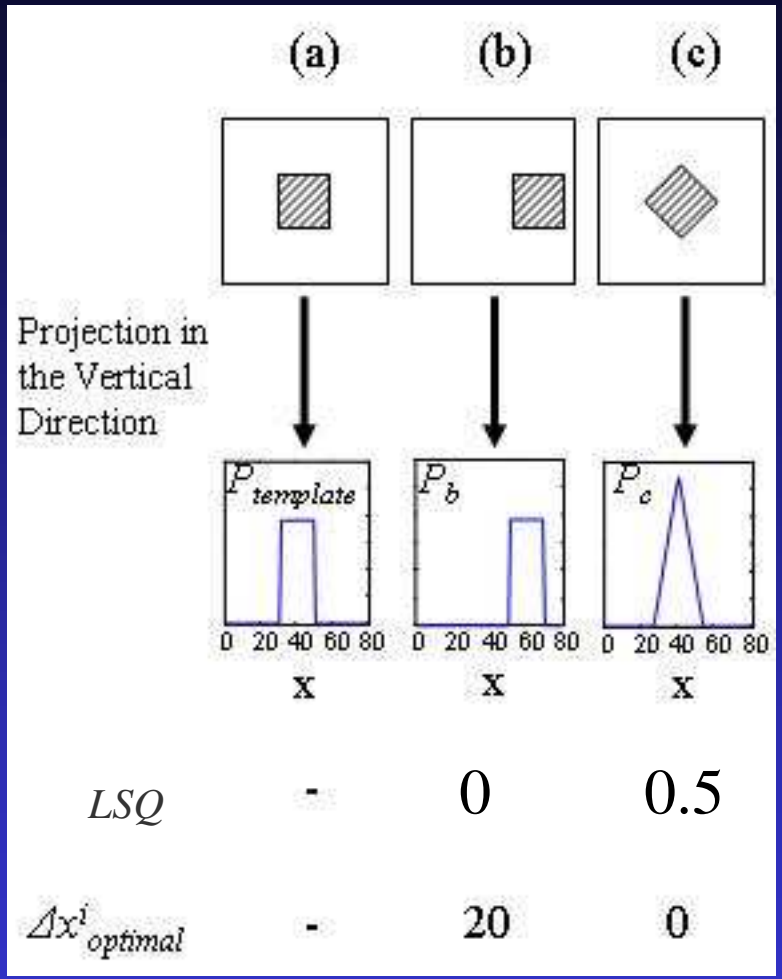
CORRECTING FOR MOTION

- IDEA: Select data acquired when $LSQ_i(\Delta x)$ is minimal for the corresponding navigator $LSQ_i(\Delta x) = [P_{ref}(x) - P_i(\Delta x)]^2; \quad i = 1,\ldots,n$

Correct for displacement

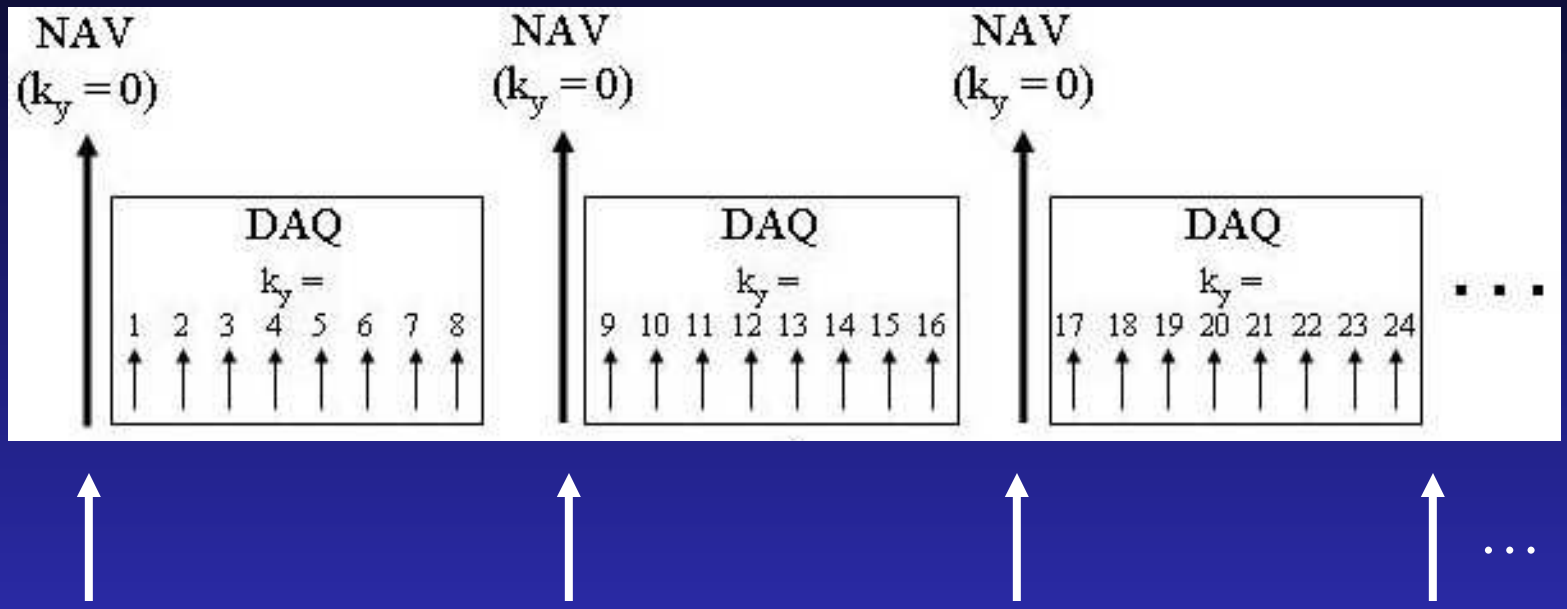


SIMILARITY-BASED NAVIGATOR ECHO



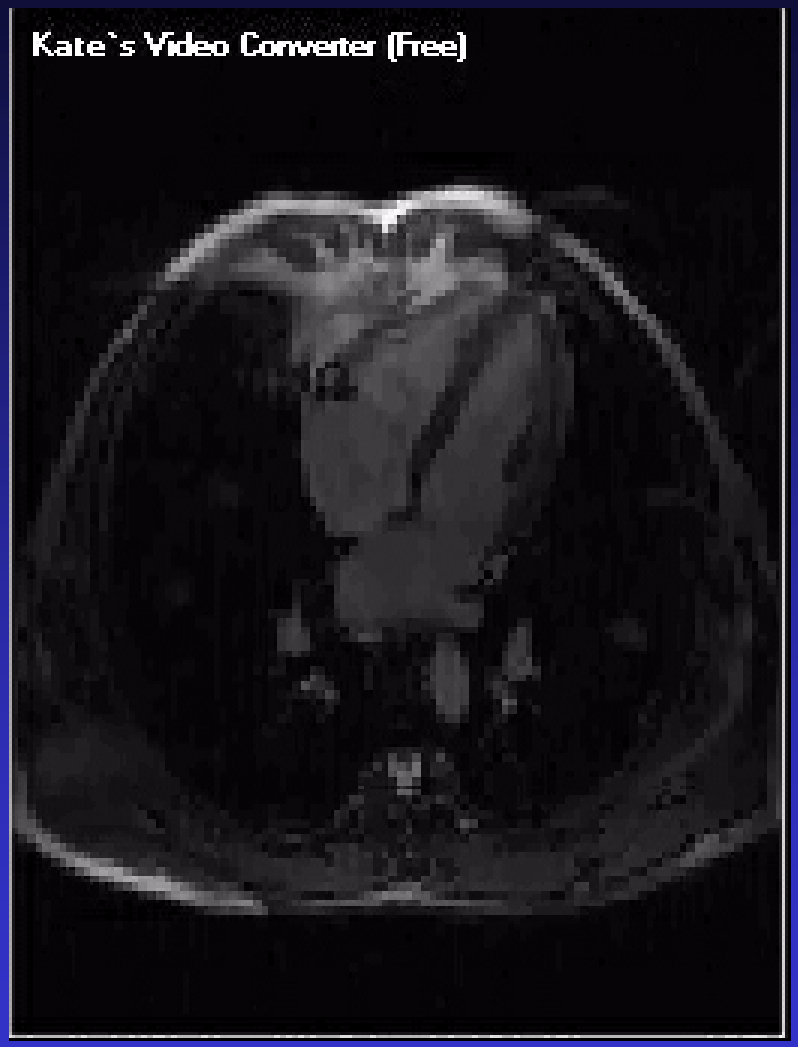
- Can set similarity threshold (as opposed to displacement threshold) for selecting data

ADDING IN TEMPORAL INFORMATION



- Can use any or all navigator lines as a reference
  - Select data independently for each reference
  - Movies!

EXAMPLES



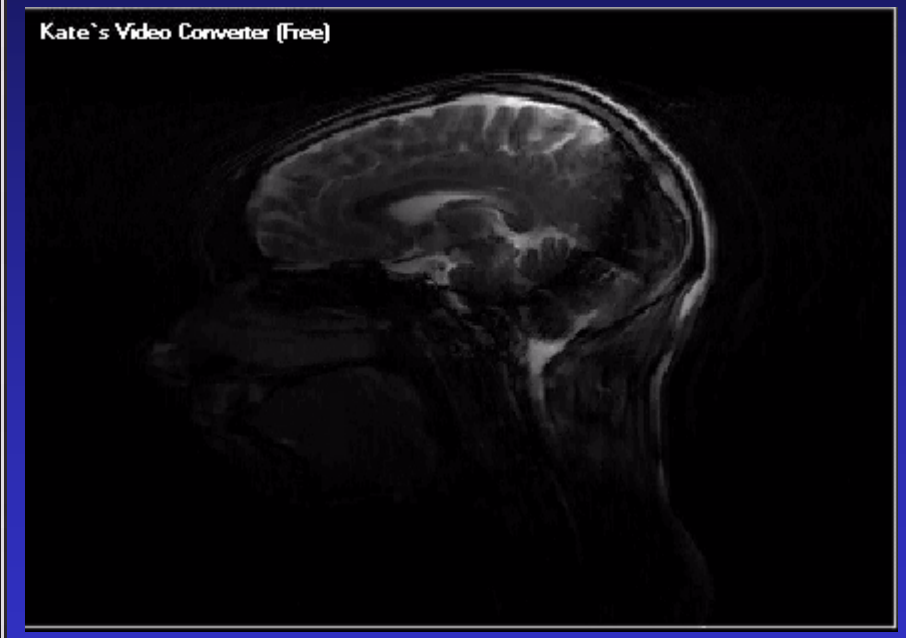
Example

EXAMPLES

Arrhythmia

EXAMPLES

WRIST



HEAD

SUMMARY

- Motion during an MR scan leads to errors in the images
- Conventional methods of dealing with cardiac motion search for data with minimal relative displacement
  - May not be adequate to deal with complex, 3D deformable cardiac displacement
- Searching for similar data allows one to suppress the effect of motion of almost arbitrary complexity

Funding provided by: Ontario Research and Development Challenge Fund (ORDCF)
Ontario Research Fund (ORF)