Image Registration
Lecture 22: Detecting Failure & Assessing Success

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Introduction

- The last component in a registration embedded system is often the determination of the quality of alignment, i.e. success for failure
- The alignment need not to be perfect, but it must be adequate for the problem at hand.
- How to measure the degree of alignment?

Measure of Success

- Quality of alignment has been estimated in published work
  - by visual inspection,
  - by comparison with a gold standard, or
  - by some self-consistency measure
- Two distinct notion of success:
  - for a class of image pairs
  - for a given image pair

Target Registration Error

- We have been using this type of error
- Let *(p,q)* be the pair of corresponding points in the 2 images and *T* the mapping that takes the 1st image to the 2nd.

$$TRE = T(p) - q$$

- Often, only the magnitude of *TRE* is reported.

Fiducial Registration Error

- Very similar to *TRE*, but applies only to "fiducial" features.
- Fiducial features are selected because of their locatability
  - Easily visible anatomical features
  - Centroid of specially designed fiducial markers affixed to the anatomy before imaging

Comparison between TRE & FRE

- TRE is more meaningful than FRE
  - TRE measured at clinically relevant point, whereas FRE limited to fiducial points
  - FRE may over- or underestimate registration error.
    - Why?
- Other measures:
  - Distance between lines
  - Distance between surfaces
  - Angular displacement for rigid-body xform

Methods for Verification

- Compare with a *ground truth* transformation
  - Some gold standard registration system with accuracy known to be high.
- Registration Circuits
  - Consistency measure among a set of images

Gold Standards

- May be based on
  - computer simulation,
  - phantoms (better for development work),
  - Cadavers (limited due to changes at death), or
  - Patients (most difficult choice)

Computer Simulations

- Computer simulations are image pairs generated by computer.
- Possible to produce both images, but often one is simulated from another using known geometrical transformation.
- Advantages:
  - Transformation is know exactly
  - Transformation is readily available
- Disavantages:
  - Lack of realism due to anatomical changes, such as respiration, cardiac cycle, etc

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- Providing an upper bound on success
  - Useful for system under development
- Intramodality registration
  - Using only geometrical transformation
  - Due to interpolation issues, images with isotropic voxel/pixel are preferred, such as MR volumes.
- Intermodality registration
  - Identify tissue types
  - Generate new graylevel values according to the physical processes of the 2nd image modality

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Target Features

- Stereotatic frame attached to the skull
- Appropriate only for rigid anatomy because all positioning is measured relative to the frame
- Providing easier and reliable verification, since neither the anatomy nor the pathology are involved in frame-base registration

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Fiducial Marker Systems

- Fiducial markers are implanted on the skull or skin.
- Excellent gold standard for both intramodality and intermodality
- Disadvantages:
  - High invasiveness
  - Subject to relative motion of the marker and anatomy between image acquisitions. More so for skin-attached markers

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Registration Circuits

- A consistency measure involving at least three images of the same modality.
- By independently registering A->B, B->C, and C->A, a target point in A can be mapped using the circuit back to A.
- Serious weakness is the assumption that the errors between registrations are uncorrelated
  - Inevitably violated, since successive registrations, A->B and B->C, say, share a common image (B).

Conclusion

- Improving registration accuracy is an important goal.
- But without a means of validation, no registration method can be accepted as a clinical tool.