New developments and improvements in Deformable Image Registration

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Outline

• Introduction
  ➔ Motivation and objectives

• Methodology
  ➔ Common framework
  ➔ Examples

• Ongoing projects at the MUW
  ➔ Autocontouring
  ➔ Featurelets

• New trends / Ideas

• Conclusion
Motivation - Why the strong need for DIR

Patient anatomy changes over time

Planning

Treatment

Uterus

Bladder
Motivation - Why the strong need for DIR

- With deformable image registration we can:
  - Dose accumulation
  - Auto contouring (atlas based)
  - Contour propagation (Planning CT to weekly CT)
  - Multi modal image manual contour guidance
Motivation - Typical challenges to solve

- Different image content between modalities
- Very big deformations
- Appearing / Disappearing tissue
- **Validation!** (very important, see next talk)
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How does it work - basic framework

How does it work

A. Geometric Transformations Derived From Physical Models
B. Geometric Transformations Derived From Interpolation Theory
C. Knowledge-based Geometric Transformations
D. Task-Specific Constraints

II. Deformation Models

Deformation field

DIR

III. Matching Criteria

New parameters

Merit value

IV. Optimization Methods

How does it work

How does it work

How does it work

How does it work

Simple example

B-spline + Image based similarity
Simple example

B-spline + Image based similarity
Making it more complex

• Clinical research version software from commercial vendors
• DIR software containing some of the latest improvements
• Combined approach between image and model based
  ➔ Image similarity measure
  ➔ Grid regularization
  ➔ Shape based regularization
  ➔ Controlling structures are used

Making it more complex - objective function

\[ f(v) = \alpha C(v) + (\beta H(v) + \gamma S(v)) + \delta D(v) \]

Regularization of the deformation field


Regularization of the deformation field

Penalize „non-intuitive deformations“

Guiding structures

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Autocontouring for cervical cancer patients

- We used as atlas to contour CTs or CBCTs:
  - Planning CT
  - One weekly CT scan with comparable bladder volume
  - One weekly CT scans with comparable uterus position
  - Several atlases “stapled” together (using several comparable structures)
  - Same with pre delineation to guide DIR
Autocontouring - Results

- Atlases with comparable bladder volume work better
- Effect less pronounced for the target

Figure B. Auto-contouring using the Dice Similarity Index (DSI) showing that using only the planning CT as atlas did not result in convincing contour quality for the bladder and the target volume. Using a scan with a comparable bladder volume the results improved. (Data (x-axis) in chronological order).
Autocontouring - Results

- Always below the intra-observer variability
- Both evaluated methods quite similar
Contours in real life
Contours in real life
Head and Neck
Head and Neck

CT week 0

CT week 4
Conclusion

- Results are reasonable...

- But still there are a lot of issues
  - Structures need correcting
  - DICE scores are relatively low

- Method is more elaborate and leads theoretically to better DFs but...
  - Cannot control optimization parameters
  - Cannot assess the influence of all the parts of the objective function

Method still a “grey” box…
New developments - Featurelets

- Piecewise rigid registration method
  - Image is divided in sub-regions (featurelets)
  - Each featurelet is registered on the target image
  - Deformation field constructed from the displacements

- As with other methods
  - Model independent - purely intensity based
  - The original idea contains minimization of elastic energy, though
New developments - Featurelets

New developments - Featurelets
Featurelets - Previous results

• Applied on 2 phantoms, lung and pelvic cases
• Comparison with commercial software

Featurelets - Influence of different featurelet size

10³ voxel

15³ voxel

35³ voxel
Featurelets - Conclusion

• Simple method

• Results are in line with similar approaches

• Future plans:
  ➡ GPU implementation
  ➡ DF regularization
  ➡ Fixing structures
  ➡ Etc...
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New trends / Ideas

• Initial Guess
  ➔ Manual: how to do it?
  ➔ Atlas based - find the image that most resembles your target
  ➔ With automatic anatomical landmark annotation

New trends / Ideas

Regional constraints: bone should not deform or should only piecewise deform

König et. al. OC-0409: Deformable image registration with guaranteed local rigidity, Radiotherapy and Oncology, Volume 115, S197 - S198
New trends / Ideas

Regional constraints: sliding organs or regions

New trends / Ideas

- Modeling the way humans deal with “invisible” organ boundaries
  ➔ We make a lot of assumptions based on prior knowledge and we “interpolate”
New trends / Ideas

“Regmentation”: joint optimization of segmentation and registration metrics

\[ f(v) = \alpha C(v) + (\beta H(v) + \gamma S(v)) + \delta D(v) \]

Discussion / Conclusions

- Strong need for DIR
- Many new improvements
- Still a bit disappointing...
- Many things to do in the future
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http://www.meduniwien.ac.at/hp/radonc/

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