The Insight Toolkit

Medical Image Segmentation and Registration

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Outline

- Spatial Objects
- Clinical Applications
Spatial Objects
Spatial Objects

- Goal of medical image analysis is object analysis

- Segmentation, Registration, Surgical Planning, Surgical Guidance, …
  - Focus on forming and manipulating a scene of objects
  - Objects with non-image properties
    - Elasticity, Viscosity, … for Registration
    - Name, ID, text
    - Haptic forces
● Data container independent
● Consistent API
● Wrapper to Image, Mesh, FEM, SpatialFunctions and other concepts in ITK

● Why establish a common API?
  – Marching cubes
  – Registration
  – Image generation
  – Model-based segmentation
  – Model-to-image registration
  – Results of segmentation
  – …
  ● All provided by basic API
Spatial Objects

- **Scene**
  - List of root spatial objects

- **Spatial Objects**
  - IsInside
  - IsEvaluableAt
  - ValueAt / DerivativeAt
  - BoundingBox
  - Resolution (of the data from which the instance was generated)
  - AffineTransform (wrt Parent Object and World)
  - Children
  - Properties
Spatial Objects

- Group
- Blob
- Surface
- Line
- Landmark
- Ellipse
- Tube

- Derived from spatial object
  - Implement: IsInside, ComputeBoundingBox, and ValueAt
Specialized Access

- ComputeBoundingBox(Levels, Type)
  - Level: 0 = no children
    1 = children
    2 = children's children
  - Type: “Tube”
    “Ellipse”
    ...

- e.g.,
  obj.ValueAt( point, 2, “Tube” );
  obj.ValueAt( point, SpatialObject::MaxDepth, NULL );
Examples

● **Surgical Planning**
  – Blob = Liver
  – Tubes = Vessels
  – Surface = Surgical Cut Path
  – Landmarks = Portal Vein Branch

● **Intra-operative guidance**
  – Liver modeling from CT
  – Ultrasound probe as an object
    ● Transform controlled by a tracker
  – Model-to-image registration (Liver model to US data)
    ● Constrained by physical properties of liver’s parts

● **Registration**
  – Rigid: example in Software Guide
  – Non-Rigid: additional parameters
Examples/Registration/Model-To-Image-Registration1.cxx
  - ImageToSpatialObjectMetric
  - OnePlusOneEvolutionaryOptimizer
  - Registration Framework

Spatial Objects:
(Easy to switch objects)

Create Objects, SpatialObjectToImageFilter, Rotate Objects, Re-register with image
typedef itk::SpatialObjectToImageFilter<
    GroupType,
    ImageType> SpatialObjectToImageFilterType;

SpatialObjectToImageFilterType::Pointer imageGenerator =
    SpatialObjectToImageFilterType::New();

imageGenerator->SetInput(group);

ImageType::SizeType size;
size[0]=200;
size[1]=200;
imageGenerator->SetSize(size);
imageGenerator->Update();

ImageType::Pointer img = imageGenerator->GetOutput();
typedef itk::GroupSpatialObject<2> GroupType;
typedef itk::EllipseSpatialObject<2> EllipseType;

EllipseType::Pointer ellipse1 = EllipseType::New();
ellipse1->SetRadius(10);
offset[0]=100;
offset[1]=40;
ellipse1->GetTransform()->SetOffset(offset);
ellipse1->ComputeGlobalTransform();

GroupType::Pointer group = GroupType::New();
group->AddSpatialObject(ellipse1);

registration->SetFixedImage(imageFilter->GetOutput());
registration->SetMovingSpatialObject(group);
registration->SetTransform(transform);
registration->SetInterpolator(interpolator.GetPointer());
registration->SetOptimizer(optimizer);
registration->SetMetric(SpatialObjectToImageMetric);
Capabilities yet explored…

- Explicit multi-scale representation API

- Atlas of objects
  - Common API for annotation
  - Means, major modes of variation, etc.
  - Instance-to-Atlas metrics

- Will be revised in itk v1.8
  - Tree structure, objects, geometric transforms as separate components
Clinical Applications
3D Ultrasound Augmentation
NCI R01: Sue Weeks MD & Julien Jomier

Pre-Operative Processing
CT / MRA acquisition
Vessels and lesions modeled

Intra-Operative Processing
Ultrasound tracking and 3D ultrasound acquisition
Patient-oriented, fused display via vessel-model-to-ultrasound-image registration
Vascular Registration Method

Fixed 3D Image (US) -> ImageToTube Metric -> Gradient Descent Optimizer

Tri-linear Interpolator -> Euler 3D Rigid Transformation

Moving Vasculature (extracted from CT)
Vascular Registration

Using 1 Processor

Using 2 Processors

<table>
<thead>
<tr>
<th>Number of Processors</th>
<th>Time/Iteration (sec)</th>
<th>Total time</th>
</tr>
</thead>
<tbody>
<tr>
<td>(512 MB)</td>
<td>0.153</td>
<td>6.31</td>
</tr>
<tr>
<td>2</td>
<td>0.297</td>
<td>12.25</td>
</tr>
</tbody>
</table>

This is 1.94 time faster!

UNC vascular registration
Ultrasound Annotation

Vessel model to image registration in 2.56 seconds – Multithreaded ITK
Dynein Arms via Models

J. Carson: EPA / Rare diseases

Quality Of Fit
--

Quality Of Fit
+

Quality Of Fit
++
Quantification of Adipose Tissue from Whole Body MRI scans

D. Metaxas (Rutgers), J. Udupa (UPenn), C. Imielinska (Columbia)

Segmented Whole-body MRI scan
(St. Luke’s-Roosevelt Hospital Obesity Research Center – Dr. Heymsfield)

Reconstructed 3D body Composition from Segmented whole body MRI scan
Computer Assisted Segmentation

R. Whitaker (Univ. of Utah), P. Ratiu (Harvard / BWH)

Accuracy

Hand 96.86 (σ = 2.6)
Assisted 98.36 (σ = 0.3)

Time

Hand 271 minutes
Assisted 73 minutes
Uterine Fibroid Growth Study
NIEHS: Barbara Davis (WHL), Richard Semelka MD

Developed by Computer-Aided Diagnosis and Display Laboratories, Sept. 2002
Breast Density Estimation

WHI: Etta Pisano MD

Original

Global Threshold - Standard

Compensate for compression

Auto threshold
Software Toolkit for Image-Guided Surgery

NIH STTR: Kevin Cleary, Georgetown
CT to X-Ray Registration
Imperial and King’s College London

3D-2D Registration
Verification of prosthesis placement
Haptics for Surgical Training
Microsoft: Mark Foskey
Small Animal Imaging

MicroPet / MicroCT
GE Corp Research
Histology to MR Registration

Benoit Paquier
Guido Gerig

DTI Analysis
Functional Image Analysis Tool

U of Iowa
• Methods in Image Analysis
BiobEng 2630 (UPitt) / 16-725 (CMU)
G. Stetten, M.D., Ph.D.

• Segmentation Methods Using ITK
Project Course (Rutgers)
D. Metaxas, Ph.D.

• Pattern Recognition and Scene Analysis
CompSci 254 (UNC)
S. Pizer, Ph.D.
Education

- Tutorials
  - IEEE Vis 2002
  - SPIE 2003
  - MICCAI 2003
  - RSNA 2003 InfoRad
  - SPIE 2004...

- Books
  - Software Guide (580 pages)
  - Theory Book

- MedIA Special Issue
Open Source + Open Data = Open Science

NCI/NIBIB CAD Workshop (Sept. 4 – 5, 2003)
  - One solution for validation:
    ITK with CAD Methods + Grid Computing (Data)

ITK + NIH Open Data Initiative
  - ITK Sets the standard for openness
  - ITK Provides methods for validation
  - ITK Provides I/O foundation for Open-data databases
  - ITK Provides platform for method distribution
The Insight Toolkit

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http://www.itk.org

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