Applications: Using Insight (itk) and The Visualization Toolkit (vtk)

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Agenda

- Approaches to interfacing vtk and itk
- Case Studies / Demos
  - Registration
    - MR/MR
    - CT/MR
  - Segmentation
    - Watershed
Motivation

- itk has no visualization capabilities
- itk has some interesting segmentation and registration algorithms
- Both itk and vtk have a pipeline architecture
- vtk has a nice wrapping facility to interpreters like tcl and python

Avoid code duplication and use “best of breed” from each toolkit.
vtk/itk Interfaces

- Connect vtk pipelines to itk pipelines
- Image filter class hierarchies
- Implement vtk filters with itk algorithms
- Callbacks for filter progress
Connect pipelines - vtk to itk

```cpp
vtkImageExport *movingExporter = vtkImageExport::New();
movingExporter->SetInput(movingReader->GetOutput());

typedef itk::VTKImageImport<InputType> ImageImportType;
ImageImportType::Pointer movingImporter = ImageImportType::New();

ConnectPipelines(movingExporter, movingImporter);
```

InsightApplications/vtkITK/Common/vtkITKUtility.h
Connect Pipelines

- Implements itk pipeline protocol, invoking vtk callbacks

  * PropagateRequestedRegion()
  * UpdateOutputInformation()
  * GenerateOutputInformation()
  * GenerateData()
vtkITK Class Hierarchies

Class Hierarchy
- `vtkITKImageToImageFilter`
  - `vtkITKImageToImageFilter`
    - `vtkITKImageToImageFilterFF`
    - `vtkITKImageToImageFilterUSUS`
    - ...
      - `vtkITKDiscreteGaussianImageFilter`
vtkITKImageToImageFilter

- Changes exception macros to errors/warnings
- Delegates
  - Modified
  - DebugOn/Off
  - SetInput/Output
  - Update
vtkITKImageToImageFilterFF

- Defines Input/Output typedefs
  
  ```cpp
  typedef float InputImagePixelType;
  typedef float OutputImagePixelType;
  typedef itk::Image<InputImagePixelType, 3> InputImageType;
  typedef itk::Image<OutputImagePixelType, 3> OutputImageType;
  ```

- Constructor
  - Creates importers/exporters
  - Connects vtk and itk pipelines
vtkITKDiscreteGaussianImageFilter

- Instantiates filter
- Delegates filter’s member data set’s/get’s
vtk Filters Implemented with itk algorithms

- vtkITKMutualInformationTransform
- Implement InternalUpdate()
  - vtkImageExport
  - itk::VTKImageImport
  - ConnectPipelines()
  - Convert vtk transform to quaternion
  - itk::RegistrationMethod
  - Convert itk quaternion to vtk transform
Illustrative Examples

Registration
Motivation for Registration

- **Intra-modality**
  - Alzheimer’s
    - Longitudinal analysis
  - CT Lung
    - Side-by-side slice reading

- **Inter-modality**
  - PET/MR/CT/US/XRAY Tomo
    - Fusion and analysis
Mutual Information Registration

- Computes “mutual information” between two datasets, a reference and target
  \[ \text{MI}(X,Y) = \text{H}(X) + \text{H}(Y) - \text{H}(X,Y) \]
- Small parameter set
- Developed by Sandy Wells (BWH) and Paul Viola (MIT) in 1995
- Defacto standard for automatic, intensity based registration
Longitudinal MRI Study

- Register multiple volumetric MRI datasets of a patient taken over an extended time
- Create a batch processing facility to process dozens of datasets
- Resample the datasets
Approach

- Validate the algorithm
- Pick a set of parameters that can be used across all the studies
- For each pair of datasets
  - Perform registration
  - Output a transform
- View the resampled source dataset in context with the target dataset
The MI Algorithm Parameter Space

- Learning Rate
- Standard Deviation of Parzen Window estimate
- Number of Samples for density estimate
- Number of Iterations
- Image variance
- Translation scale factors

GE’s Design for Six Sigma (DFSS) Design of Experiments Tool
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Division of Labor

**vtk**
- Read data
- Export data

** itk**
- Shrink
- Register
- Report transform

---

**Utils**
- MIRegistration.cxx

---

**vtk**
- Read data
- Reslice
- Display

---

**Utils**
- MultiCompare.tcl
The Pipeline

- vtkImageReader
- vtkImageExport
- itk::vtkImporter
- itk::NormalizeImageFilter
- itk::ShrinkImageFilter
- itk::ImageRegistrationMethod
- vtkTransform
Oregon Data

- 25 Registrations
- 13 Subjects, some with AD
- Qualitative comparison
- One set of parameters for all studies

Data Courtesy of Jeffrey Kaye, Oregon Health Sciences Center
Longitudinal MRI
No Registration

Source
Original image

Checkerboard

Target
Original image

Difference

Position: -0.426594 9.43833 1.30474
Orientation: 2.58177 7.81998 0.940923

Study: ../Kaye/114_0744/e1
Study: ../Kaye/114_1951/e1
Longitudinal MRI Registration

Source Original image

Checkerboard

Target Original image

Position: -0.426594 9.43833 1.30474
Orientation: 2.5817 7.61998 0.948923

Difference

Study: ../Kaye/114_0744/e1
Study: ../Kaye/114_1951/e1
Multi Field MRI Data

- Register 1.5T and 3T to 4T data
- Resampled 1.5T and 3T to correspond to the 4T sampling
- Volume rendering of the 3 datasets from the same view

- Demo mri1.bat, MultiCompareAD.tcl

InsightApplications/MRIRegistration
1.5T vs 4T MRI
No Registration

Checkerboard
Source Original Image
Difference
Target Original Image
1.5T vs 4T MRI Registration
3D Visualization of the same subject
Scanned with different MR field Strengths

3T

1.5T

4T

All Registered To 4T
CT Lung Longitudinal Study

- Register two CT exams of the same patient taken at two different times
- Side-by-side synchronized view for visual comparison
Lung CT No Registration
Lung CT Registration

Source Original Image

Checkerboard

Target Original Image

Difference
microPet/Volume CT
Demo CT/MR fusion
Implementing a vtk Transform with itk

- vtkITKMutualInformationTransform

DemoMutual.tcl
Visible Woman Registration
Case Study

Bill Lorensen, GE Research
Peter Ratiu, Brigham and Womens Hospital
Agenda

- Problem Statement
- Methods
- Results
- Discussion
Problem Statement

- Register the Visible Human Female Computed Tomography and MRI Data to the cryo-section data
- Validate the use of the itk Mutual Information Registration algorithm on data of differing modalities
- Assess the performance of the registration using landmarks selected by an anatomical expert
Methods

- NormalizeImageFilter (itk)
- Mutual Information Registration (itk)
  - Implemented as a vtk Transform
- Marching Cubes (vtk)
- Checkerboard Display (vtk)
Methods

- Multiple registration runs with increasing scales
- Both RGB and CT data scaled to zero mean and unit variance
- $1/16$, $1/8$, $\frac{1}{4}$, $\frac{1}{2}$, 1 scale
- $0.01$, $0.01$, $0.004$, $0.004$, $0.001$ learning rate
- 2000 iterations at each resolution
- Initial vertical translation of 20 mm
- Checkerboard display of two modalities after each resolution run
CT Results

- Generated isosurfaces of skin and bone from CT data
- Transformed according to computed transformation
- At each triangle vertex, sample the RGB data to color the vertex
CT Results

- CT Landmarks transformed by Mutual Information matrix into RGB coordinate system
- Compute distance between CT and RGB points at each iteration
Distances Between Corresponding Key Points
MR Results

- Initial transform computed using experts anatomical landmarks as correspondences
- Same parameter schedule as CT/RGB
MRI Results

- MRI Landmarks transformed by Mutual Information matrix into RGB coordinate system
- Compute distance between MRI and RGB points at each iteration
Distances Between Corresponding Key Points

![Graph showing distances between corresponding key points over iterations. The x-axis represents iteration, and the y-axis represents distance in millimeters. Several lines of different colors and styles represent different key point pairs, with each line connecting points at corresponding iterations to show distance changes.]
CT to RGB rigid body registration is a good first step for subsequent deformable registration.
MRI Discussion

- MRI to RGB registration was not effective
  - Too much anatomical distortion occurred between the MR and RGB acquisitions
Watershed Segmentation

- I/O and Visualization with vtk
- Image processing and segmentation with itk
- User interface with tk
- Prototype in tcl
Demo Watershed
Applications: Using Insight(itk) and The Visualization Toolkit(vtk)

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