Slicer annotations for the Quantitative Imaging Network

Andrey Fedorov
Iowa Slicer/QIN workshop
19-22 March 2012
Outline

- Out-of-the-box infrastructure for annotations in Slicer 4
- Formats for “structured” annotations
- “Structured” annotations in Slicer 4: status and plans
Slicer Annotations “language”:
- Fiducial (point)
- Ruler (2d measurement)
- ROI (3d box)

Name and Description can be added

Saved as part of Slicer scene (XML-based MRML format)
Annotations in Slicer 4

+ labels (3d segmentations) – Editor module
Stored as labeled volumes
1. MRML is a format specific to 3D Slicer
2. There is no direct association between annotations/labels and volumes being annotated
Primary motivation comes from radiology practice:

• “Structure” of most common radiologic reports: “Finding” and “Impression” sections dictated

• Difficult to use for research, data mining, confusion possible even while exchanging reports among radiologists

• No explicit connection of the report to the image finding

• Need structure, vocabulary, connection to the finding in the image
DICOM SR = DICOM Structured Reporting
Industrial and ISO standard, part of DICOM as of 2000
Structured, self-contained, tree-based encoding
Image (2D) and patient (3D) relative coordinates
Vocabulary-based annotation and markup
Can contain references to other DICOM objects (segmentation objects, RT structure sets)

Tools:
  Developer-level: DCMTK C++ API, Java PixelMed, dcm4che; commercial: Merge (C++, Java)
  User-level: commercial packages (Siemens syngo.via)

Easily transcoded into/from XML (supported by toolkits)

```xml
<scoord ID="ci_1.16.15.4.6.1.1" relationship="INFERRED FROM">
  <concept cm="Source of Measurement" csd="DCM" cv="121112" />
  <point><x>184.249114990234</x><y>86.3667602539063</y></point>
  <image ID="ci_1.16.15.4.6.1.1.1" relationship="SELECTED FROM">
    <class>1.2.840.10008.5.1.4.1.1.2</class>
    <instance>1.3.6.1.4.1.14519.5.2.1.1706.4001.205946621458421023876774752989</instance>
  </image>
</scoord>
```
Tree of content

C.Z.4 SR Content Tree Example (Informative)

Figure C.Z.4-1 depicts the content of an example diagnostic interpretation.

- Document Root Node CONTAINER
  - "diagnostic report" (document type)
  - contains
    - BV
      - Content Node CODE "finding = mass"
      - Leaf Node DICOM Image "purpose = best illustration of findings"
    - BV
      - Heading Node CONTAINER "Conclusions"
      - contains
        - BV
          - Heading Node CONTAINER "Specific Image Findings"
          - contains
            - BV
              - Content Node CODE "conclusion = probable malignancy"
            - BV
              - Content node SCOORD "purpose = epicenter of mass"
            - inferred from
              - BR

- Relationship Modes
  - BV = By-value
  - BR = By-reference
Tree elements

Value types (CONTAINER, CODE, TEXT, SCOORD)

Relationships ("contains", "has properties", "inferred from")

Markup: SCOORD

POINT, MULTIPOINT, POLYLINE, CIRCLE, ELLIPSE

Pixel coordinates
Clinical user view

Chest X-ray Report:
Observer: Clunie^David^A^Dr.
History: malignant melanoma excised 1Y
Findings:
- finding: multiple masses in both lung fields
- best illustration of findings:
Conclusions:
- conclusion: cannon-ball metastases
- conclusion: recurrent malignant melanoma
Diagnosis Codes:
- diagnosis: 172.9/ICD9
- diagnosis: 197.0/ICD9

FIGURE 1. Simple example of a DICOM Structured Report

AIM = Annotation Image Markup

Information model that defines structure in organizing the information derived from images

XML based
- Defined by an XML schema
- XML for serialization

Tools
- Developer-level: C++ API (Windows only), Java API (in development)
- User-level: OsiriX iPAD (Mac only), ClearCanvas (Windows only) – not mutually compatible

```xml
<GeometricShape cagridId="0" includeFlag="true" shapeIdentifier="1"
xsi:type="Polyline">
  <spatialCoordinateCollection>
    <SpatialCoordinate cagridId="0" coordinateIndex="0"
imageReferenceUID="1.3.6.1.4.1.14519.5.2.1.1706.4001.205946621458421023876774752989" referencedFrameNumber="1" x="184.249114990234" y="86.3667602539063" xsi:type="TwoDimensionSpatialCoordinate"/>
  </spatialCoordinateCollection>
</GeometricShape>
```
Terminology:

An image *annotation* is the explanatory or descriptive information about the pixel data of an image that is generated by a human or machine observer.

An image *markup* is the graphical symbols placed over the image to depict an annotation.
Channin et al. (2010). The caBIG annotation and image Markup project. Journal of digital imaging : the official journal of the Society for Computer Applications in Radiology, 23(2), 217-25
Fig 5. Markup group.
The AIM template XML schema allows to create an XML document containing controlled questions and answers based on known vocabularies such as SNOMED CT, RadLex, LOINC, etc. as well as user-defined terminologies.

DICOM SR templates – similar purpose, vocabularies
### Template Components

**2-Non-Measurable Disease Evaluation of Non-Measurable Disease**

<table>
<thead>
<tr>
<th>Term (code meaning)</th>
<th>Code</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stable Disease</td>
<td>RANO1</td>
<td>RANO</td>
</tr>
<tr>
<td>Progressive Disease</td>
<td>RANO4</td>
<td>RANO</td>
</tr>
<tr>
<td>Baseline</td>
<td>RANO0</td>
<td>RANO</td>
</tr>
<tr>
<td>Not Present</td>
<td>RANO5</td>
<td>RANO</td>
</tr>
<tr>
<td>Non-evaluable</td>
<td>RANO6</td>
<td>RANO</td>
</tr>
</tbody>
</table>

**3-FLAIR**

Tumor Evaluation on FLAIR

<table>
<thead>
<tr>
<th>Term (code meaning)</th>
<th>Code</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stable Disease</td>
<td>RANO1</td>
<td>RANO</td>
</tr>
<tr>
<td>Progressive Disease</td>
<td>RANO4</td>
<td>RANO</td>
</tr>
<tr>
<td>Baseline</td>
<td>RANO0</td>
<td>RANO</td>
</tr>
<tr>
<td>Not Present</td>
<td>RANO5</td>
<td>RANO</td>
</tr>
<tr>
<td>Non-evaluable</td>
<td>RANO6</td>
<td>RANO</td>
</tr>
</tbody>
</table>

**1-Measurable Disease Presence or Absence of Measurable Disease**

<table>
<thead>
<tr>
<th>Term (code meaning)</th>
<th>Code</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>RANO7</td>
<td>RANO</td>
</tr>
<tr>
<td>No</td>
<td>RANO8</td>
<td>RANO</td>
</tr>
<tr>
<td>Not Evaluable</td>
<td>RANO6</td>
<td>RANO</td>
</tr>
</tbody>
</table>
AIM vs DICOM SR

Nothing is perfect

- AIM: limited support by user-level tools, limited developer-level tools, few users, few use cases
- DICOM SR: no publicly available user-level tools, requires DICOM expertise for usage/understanding, limited support by commercial tools

AIM – DICOM SR conversion is possible for AIM 3.0 compliant annotations using AIM 3.0 API (caBIG/Northwestern)

Caveat: may not be interoperable with other AIM versions and DICOM SR tools
Example

Revised Assessment in Neuro-Oncology (RANO) template
Courtesy Jayashree Kalpathy-Cramer (MGH)
ClearCanvas TCGA WS
AIM Annotation

<?xml version="1.0" encoding="UTF-8" standalone="no" ?>
<ImageAnnotation xmlns="gme://caCORE.caCORE/3.2/edu.northwestern.radiology.AIM" aimVersion="3.0" cagridId="0" codeMeaning="Response Assessment in Neuro-Oncology" codeValue="RANO" codingSchemeDesignator="RANO" dateTime="2012-01-09T19:09:58" name="BreastDx-01-0068_andrey_2012-01-09 19:09 PM" uniqueIdentifier="1.3.6.1.4.1.25403.8796750565674.2788.20120109070958.2" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xsi:schemaLocation="gme://caCORE.caCORE/3.2/edu.northwestern.radiology.AIM AIM_v3_rv11_XML.xsd">
AIM Annotation cont.

<inferenceCollection>
  <Inference cagridId="0" codeMeaning="Yes" codeValue="RANO7" codingSchemeDesignator="RANO" codingSchemeVersion="" imageEvidence="true"/>
  <Inference cagridId="0" codeMeaning="Progressive Disease" codeValue="RANO4" codingSchemeDesignator="RANO" codingSchemeVersion="" imageEvidence="true"/>
  <Inference cagridId="0" codeMeaning="Stable Disease" codeValue="RANO1" codingSchemeDesignator="RANO" codingSchemeVersion="" imageEvidence="true"/>
</inferenceCollection>

<user>
  <User cagridId="0" loginName="andrey" name="andrey" numberWithinRoleOfClinicalTrial="1" roleInTrial="Performing"/>
</user>

<equipment>
  <Equipment cagridId="0" manufacturerModelName="AIM_TCGA_v3" manufacturerName="Northwestern University" softwareVersion="3.0.0.3"/>
</equipment>

<imageReferenceCollection>
  <ImageReference cagridId="0" xsi:type="DICOMImageReference">
    <imageStudy>
      <ImageStudy cagridId="0" instanceUID="1.3.6.1.4.1.14519.5.2.1.4792.2001.200235584781096359647374535914" startDate="2008-06-27T00:00:00" startTime="000000"/>
      <imageSeries>
        <ImageSeries cagridId="0" instanceUID="1.3.6.1.4.1.14519.5.2.1.4792.2001.17097719803114840822588336860"/>
        <imageCollection>
          <Image cagridId="0" sopClassUID="1.2.840.10008.5.1.4.1.1.4" sopInstanceUID="1.3.6.1.4.1.14519.5.2.1.4792.2001.149982482708499901857882575988"/>
        </imageCollection>
      </imageSeries>
    </imageStudy>
  </ImageReference>
</imageReferenceCollection>
AIM Annotation cont.

```xml
<geometricShapeCollection>
  <GeometricShape cagridId="0" includeFlag="true" shapeIdentifier="0" xsi:type="MultiPoint">
    <spatialCoordinateCollection>
      <SpatialCoordinate cagridId="0" coordinateIndex="0"
        imageReferenceUID="1.3.6.1.4.1.14519.5.2.1.4792.2001.149982482708499901857882575988"
        referencedFrameNumber="1" x="170.666656494141" xsi:type="TwoDimensionSpatialCoordinate"
        y="359.489318847656"/>
      <SpatialCoordinate cagridId="0" coordinateIndex="1"
        imageReferenceUID="1.3.6.1.4.1.14519.5.2.1.4792.2001.149982482708499901857882575988"
        referencedFrameNumber="1" x="274.156005859375" xsi:type="TwoDimensionSpatialCoordinate"
        y="337.702087402344"/>
    </spatialCoordinateCollection>
  </GeometricShape>
</geometricShapeCollection>

<person>
  <Person cagridId="0" id="BreastDx-01-0068" name="" sex="F"/>
</person>

</ImageAnnotation>
```
AIM Support in 3D Slicer

Supplement to BWH QIN grant

“[…] implement support of AIM in 3D Slicer, including storage of annotations produced by 3D Slicer in AIM format and importing AIM annotations into 3D Slicer”

Main objective: facilitate exchange of image annotations among QIN groups and beyond
Current status

3 months through the supplement-funded period (Dec 2011-July 2012)

Planned functionality motivated by QIN Use cases

Focus of our efforts to date:

• Research in understanding AIM, DICOM SR, XML
• Development of specialized module in 3D Slicer
• 3D Slicer “book-keeping” infrastructure: Support of tree-based hierarchy for keeping track of markup elements and their relation to the annotated volume
• Internal improvements can also benefit DICOM SR support in Slicer

Details and status:

• Source code in progress: [https://github.com/fedorov/Reporting](https://github.com/fedorov/Reporting)
3D Slicer Reporting module

- Correspondence bw markup/annotation is preserved by means of hierarchy
- Textual annotation limited to name field
- Points and measurements markups are supported
Next steps

Implement support for 3d segmentations

• store as binary maps, direct connection to the DICOM study being annotated

• Support serialization into DICOM segmentation objects

• “common denominator” support for text annotations: record object name

Support of export to DICOM SR under consideration
Followup

Main page for the project:

http://wiki.na-mic.org/Wiki/index.php/Projects:QIN:3D_Slicer_Annotation_Image_Markup