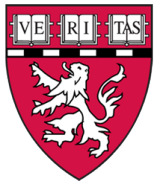
Surgical Planning Laboratory
Brigham and Women's Hospital
Boston, Massachusetts USA



a teaching affiliate of
Harvard Medical School

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

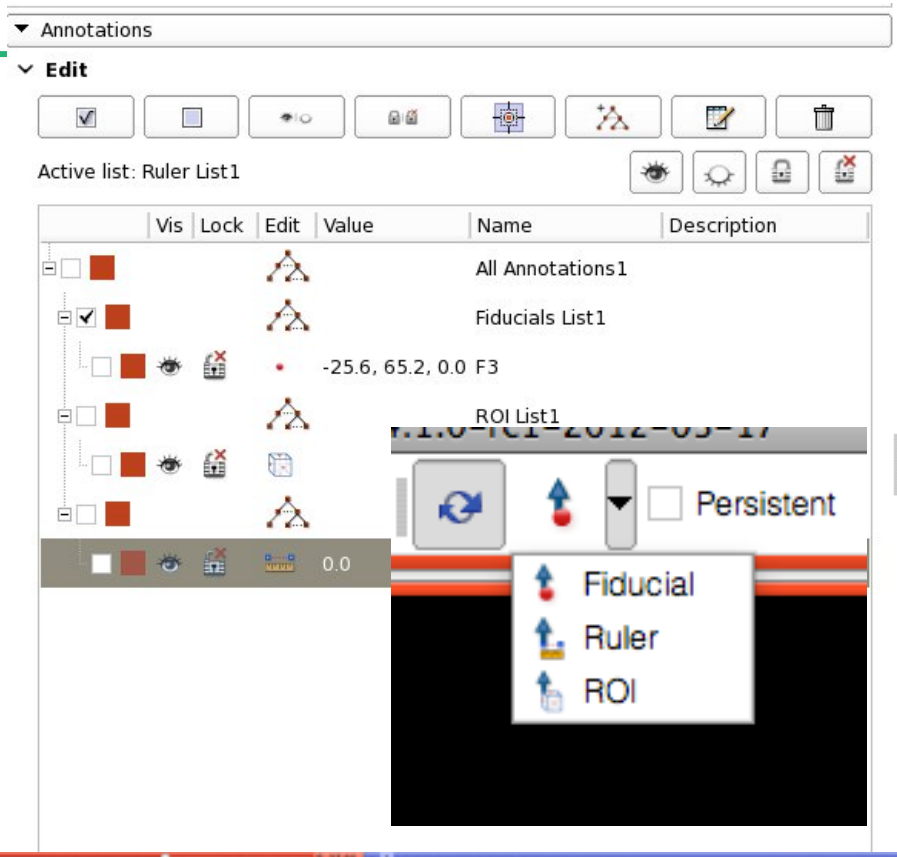
Annotations in Slicer 4

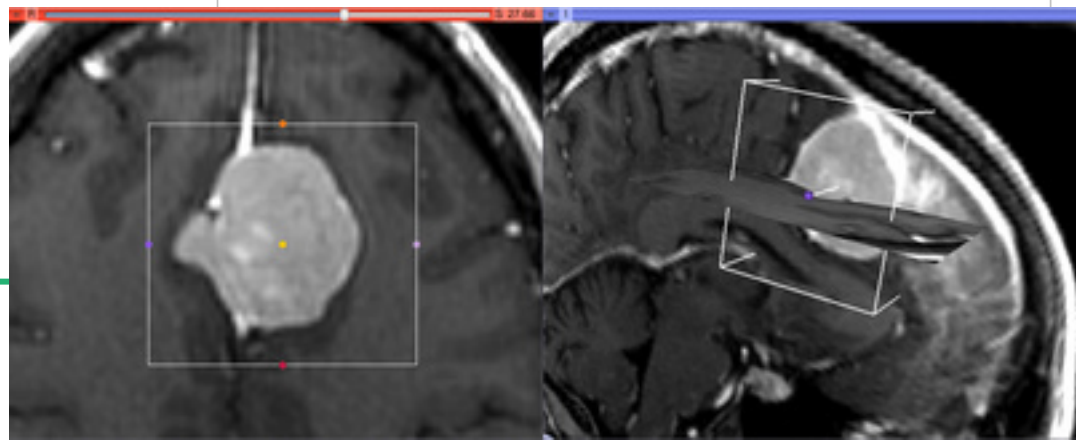
Slicer Annotations “language”:

- Fiducial (point)
- Ruler (2d measurement)
- ROI (3d box)

Name and Description can be added

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

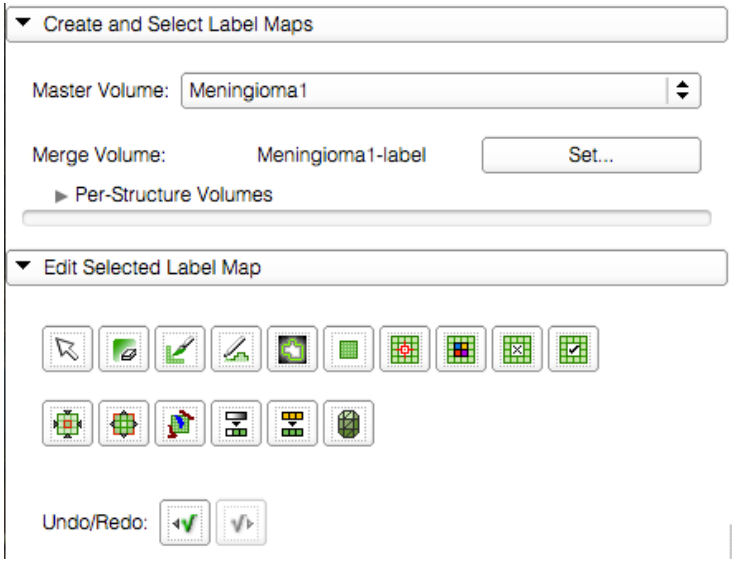


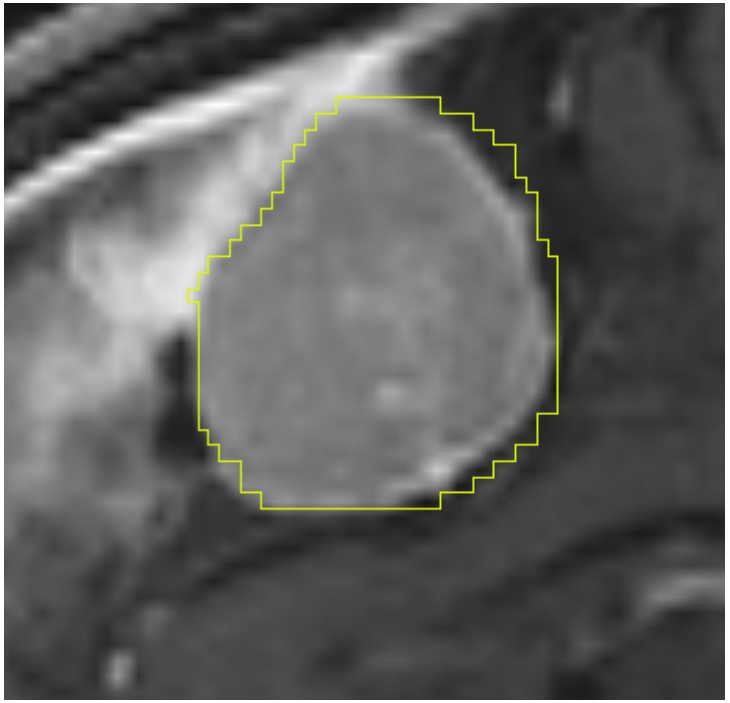


Annotations in Slicer 4

+ labels (3d segmentations) – Editor module

Stored as labeled volumes





Deficiencies

1. MRML is a format specific to 3D Slicer
2. There is no direct association between annotations/labels and volumes being annotated

Why DICOM SR/AIM?

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

Formats: DICOM SR

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)

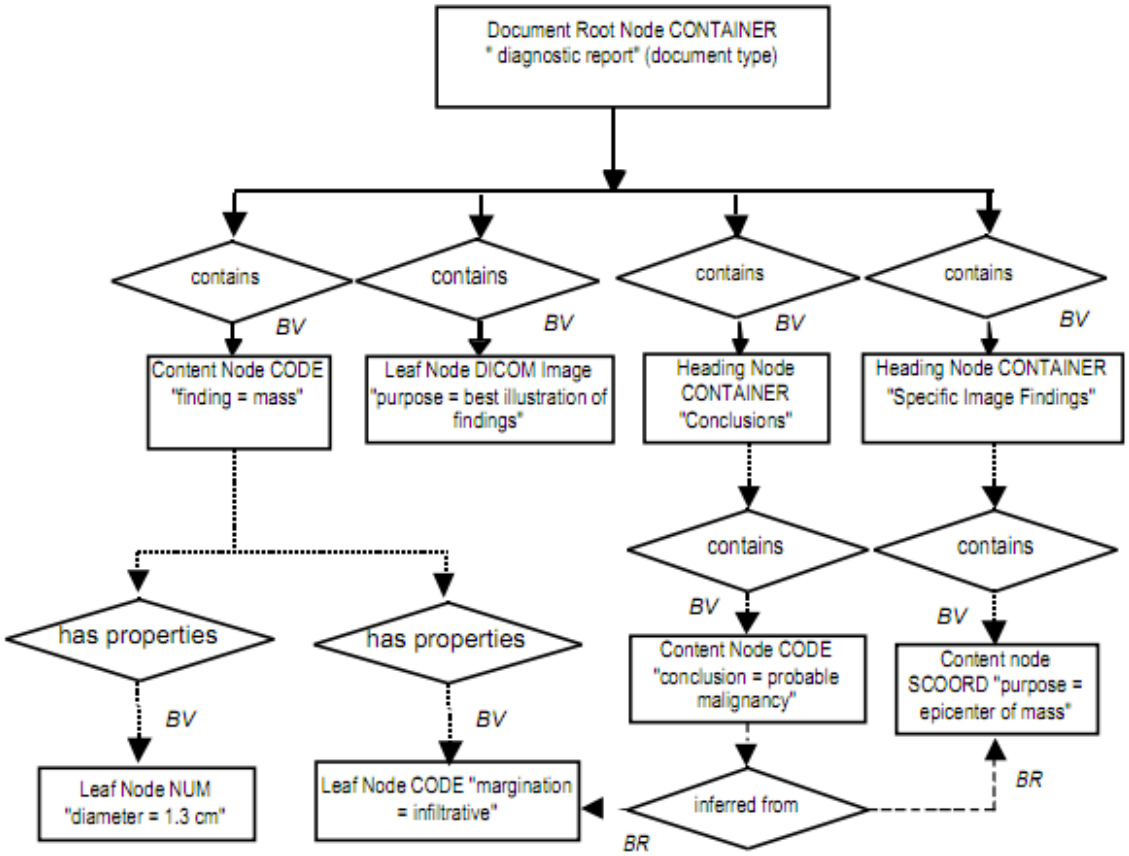
Easily transcoded into/from XML (supported by toolkits)

```
<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.



* *Relationship Modes*
BV = By-value
BR = By-reference

http://medical.nema.org/Dicom/supps/sup23_lb.pdf, p.288

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 maligant melanoma
Diagnosis Codes:
- diagnosis: 172.9/ICD9
- diagnosis: 197.0/ICD9

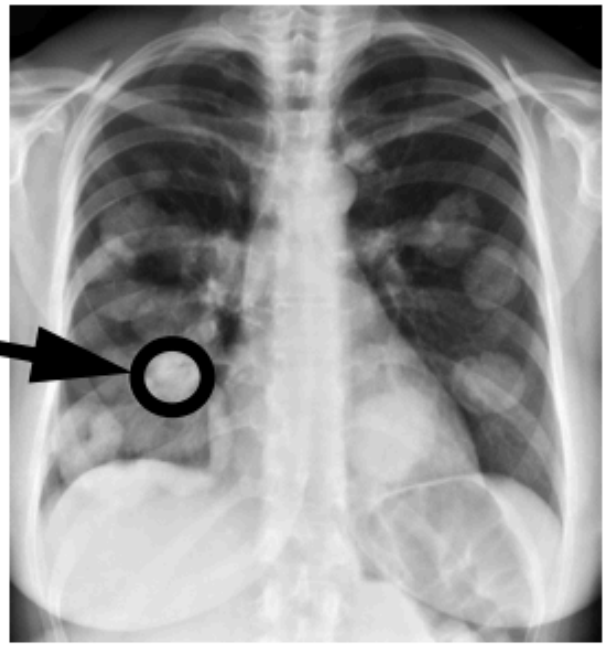


FIGURE 1. **Simple example of a DICOM Structured Report**

Clunie, D. (2000). DICOM Structured Reporting. PixelMed Publishing, p.30

Formats: AIM

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

```
<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"
xsi:type="TwoDimensionSpatialCoordinate" y="86.3667602539063"/>
```

AIM terminology

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.

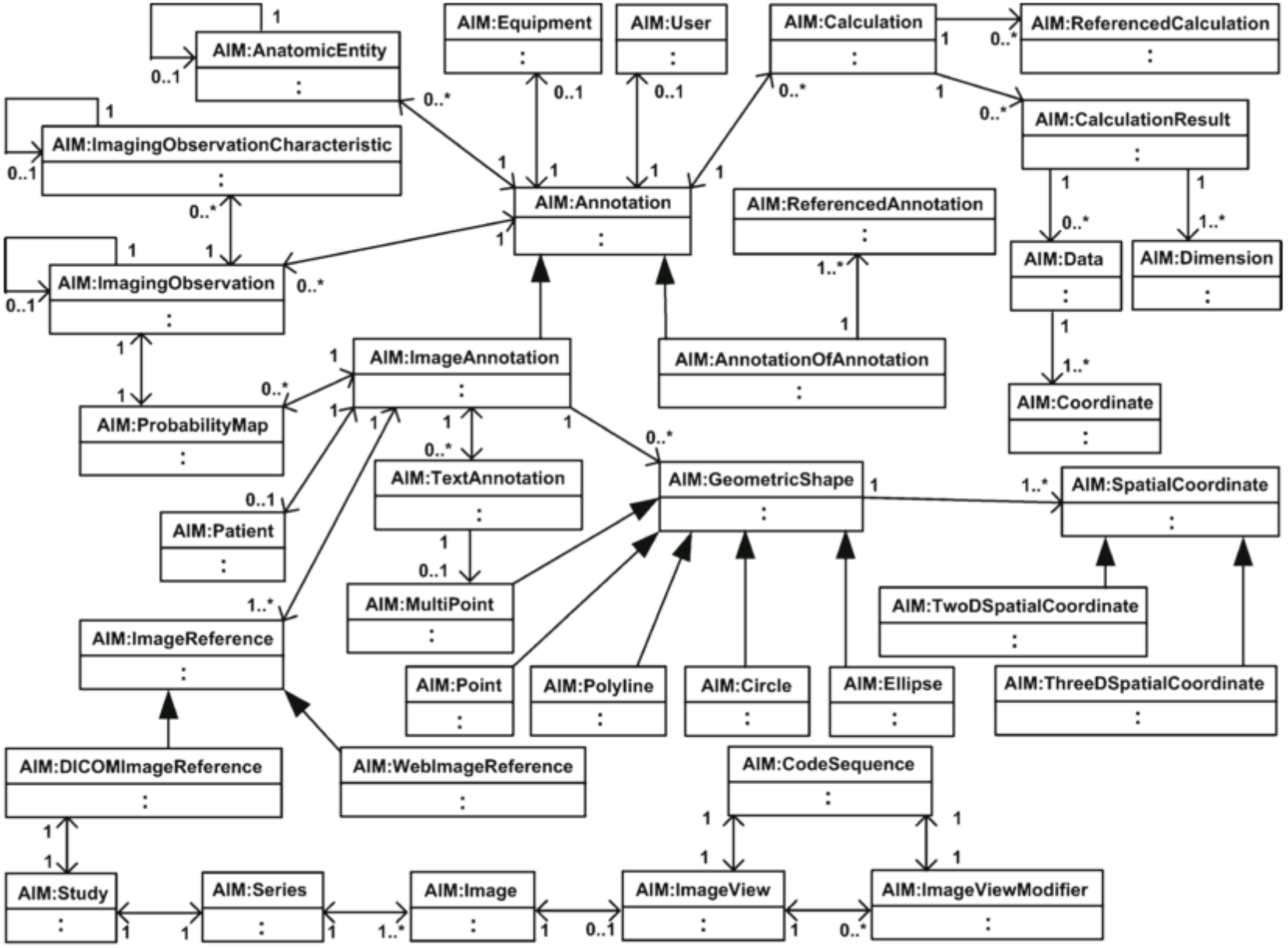


Fig 1. AIM UML Class diagram.

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

AIM Markup

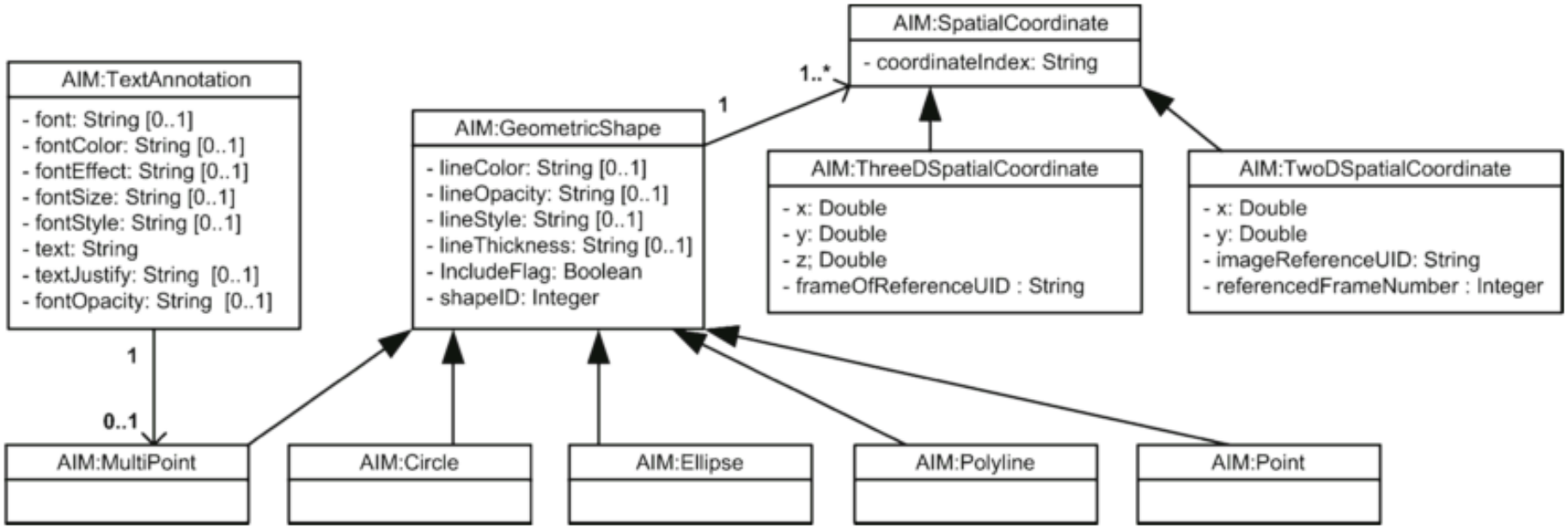
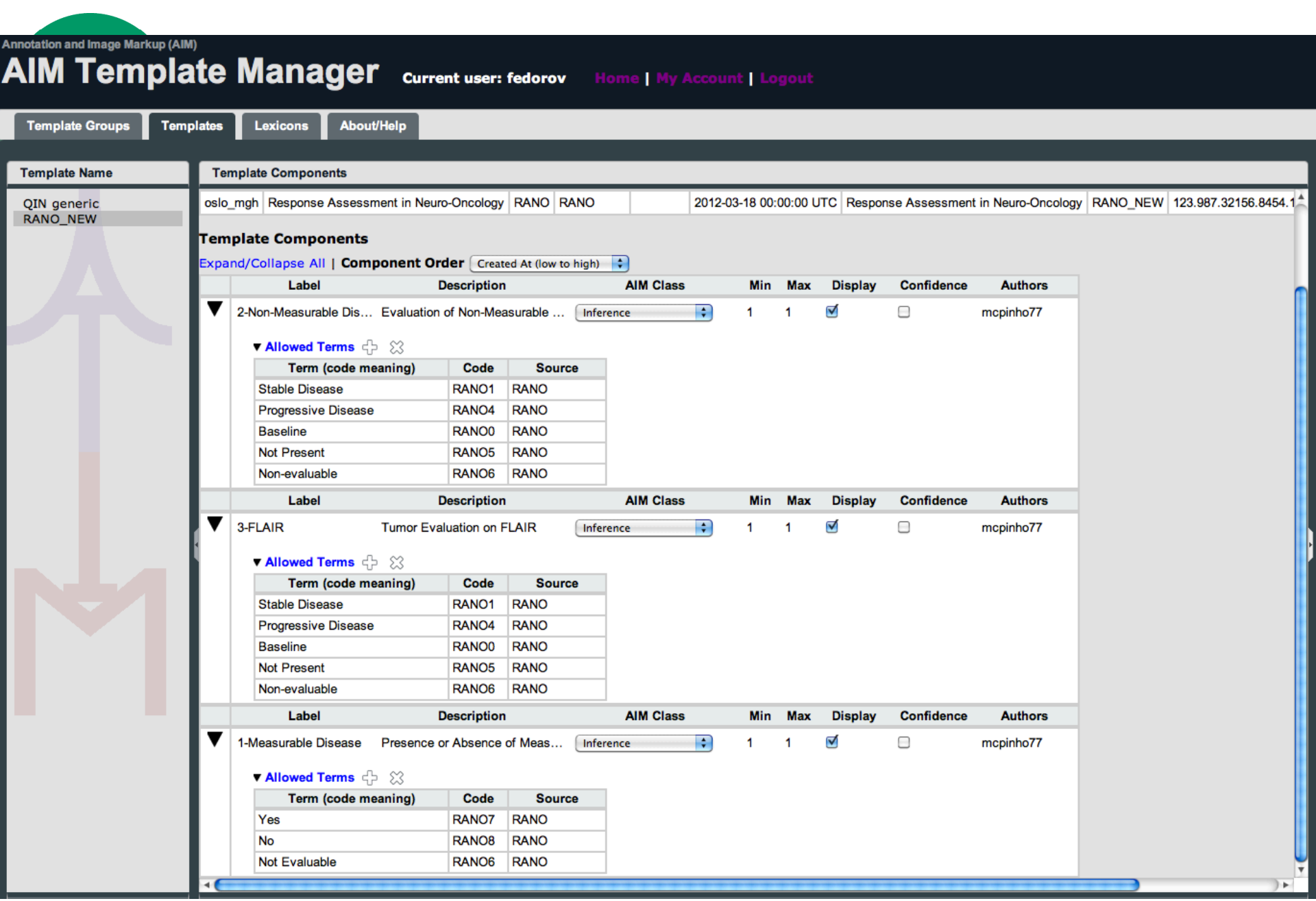


Fig 5. Markup group.

Annotation templates

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


Annotation and Image Markup (AIM)
AIM Template Manager
Current user: fedorov
Home | My Account | Logout
Template Groups
Templates
Lexicons
About/Help
Template Name
QIN generic
RANO_NEW
Template Components
oslo_mgh | Response Assessment in Neuro-Oncology | RANO | RANO | | 2012-03-18 00:00:00 UTC | Response Assessment in Neuro-Oncology | RANO_NEW | 123.987.32156.8454.1
Template Components
Expand/Collapse All | Component Order Created At (low to high)
Label | Description | AIM Class | Min | Max | Display | Confidence | Authors
2-Non-Measurable Dis… | Evaluation of Non-Measurable … | Inference | 1 | 1 | mcpinho77
Allowed Terms
Term (code meaning) | Code | Source
Stable Disease | RANO1 | RANO
Progressive Disease | RANO4 | RANO
Baseline | RANO0 | RANO
Not Present | RANO5 | RANO
Non-evaluable | RANO6 | RANO
Label | Description | AIM Class | Min | Max | Display | Confidence | Authors
3-FLAIR | Tumor Evaluation on FLAIR | Inference | 1 | 1 | mcpinho77
Allowed Terms
Term (code meaning) | Code | Source
Stable Disease | RANO1 | RANO
Progressive Disease | RANO4 | RANO
Baseline | RANO0 | RANO
Not Present | RANO5 | RANO
Non-evaluable | RANO6 | RANO
Label | Description | AIM Class | Min | Max | Display | Confidence | Authors
1-Measurable Disease | Presence or Absence of Meas… | Inference | 1 | 1 | mcpinho77
Allowed Terms
Term (code meaning) | Code | Source
Yes | RANO7 | RANO
No | RANO8 | RANO
Not Evaluable | RANO6 | RANO

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

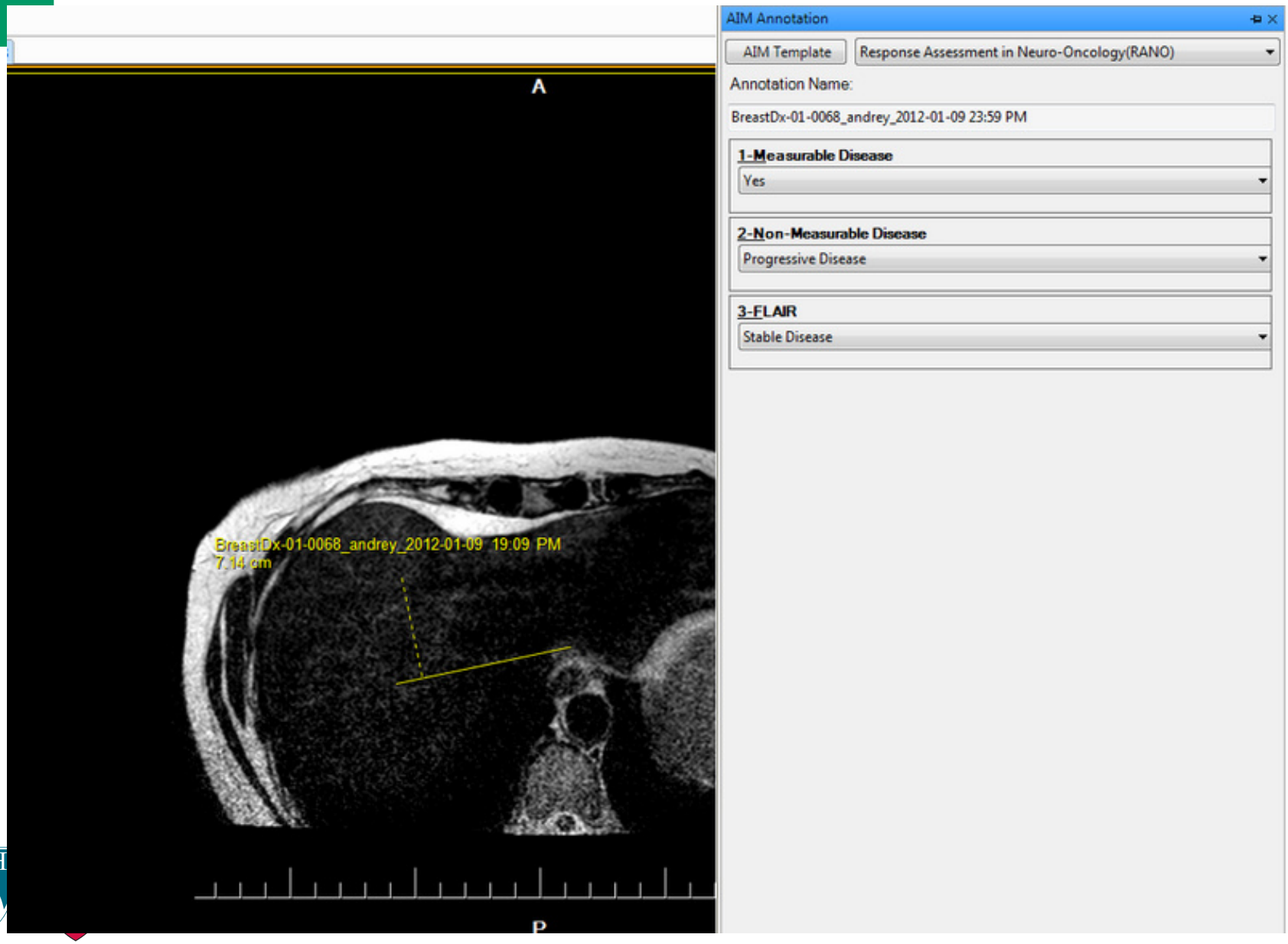
Revised Assessment in Neuro-Oncology (RANO) template

Courtesy Jayashree Kalpathy-Cramer (MGH)

RANO Template

```
<?xml version="1.0" encoding="UTF-8"?>
<TemplateContainer authors="oslo_mgh" name="RANO_NEW"
     version="1.0" description="RANO WITHOUT MEASURABLE DISEASE ASSESSMENT"
     creationDate="2011-11-18" xsi:schemaLocation="gme://caCORE.caCORE/3.2/edu.northwestern.radiology.AIMTemplate AIMTemplate_v1rv18.xsd"
     xmlns="gme://caCORE.caCORE/3.2/edu.northwestern.radiology.AIMTemplate"
     xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
  <Template name="RANO_NEW" version="1.0" authors="oslo_mgh"
      description="Response Assessment in Neuro-Oncology" uid="123.987.32156.8454.1213156464.87987"
      codeValue="RANO" codeMeaning="Response Assessment in Neuro-Oncology" codingSchemeDesignator="RANO"
      creationDate="2011-11-18">
    <Component label="2-Non-Measurable Disease" minCardinality="1" maxCardinality="1" itemNumber="1" shouldDisplay="true"
        explanatoryText="Evaluation of Non-Measurable Disease" authors="mcpinho77">
      <Inference annotatorConfidence="false"/>
      <AllowedTerm codeMeaning="Stable Disease" codeValue="RANO1" codingSchemeDesignator="RANO">
      </AllowedTerm>
      <AllowedTerm codeMeaning="Progressive Disease" codeValue="RANO4" codingSchemeDesignator="RANO">
      </AllowedTerm>
      <AllowedTerm codeMeaning="Baseline" codeValue="RANO0" codingSchemeDesignator="RANO">
      </AllowedTerm>
      <AllowedTerm codeMeaning="Not Present" codeValue="RANO5" codingSchemeDesignator="RANO">
      </AllowedTerm>
      <AllowedTerm codeMeaning="Non-evaluable" codeValue="RANO6" codingSchemeDesignator="RANO">
      </AllowedTerm>
    </Component>
    <Component label="3-FLAIR" minCardinality="1" maxCardinality="1" itemNumber="2" shouldDisplay="true"
        explanatoryText="Tumor Evaluation on FLAIR" authors="mcpinho77">
      <Inference annotatorConfidence="false"/>
      <AllowedTerm codeMeaning="Stable Disease" codeValue="RANO1" codingSchemeDesignator="RANO">
      </AllowedTerm>
      <AllowedTerm codeMeaning="Progressive Disease" codeValue="RANO4" codingSchemeDesignator="RANO">
      </AllowedTerm>
      <AllowedTerm codeMeaning="Baseline" codeValue="RANO0" codingSchemeDesignator="RANO">
      </AllowedTerm>
      <AllowedTerm codeMeaning="Not Present" codeValue="RANO5" codingSchemeDesignator="RANO">
      </AllowedTerm>
      <AllowedTerm codeMeaning="Non-evaluable" codeValue="RANO6" codingSchemeDesignator="RANO">
      </AllowedTerm>
    </Component>
    <Component label="1-Measurable Disease" minCardinality="1" maxCardinality="1" itemNumber="0"
        shouldDisplay="true" explanatoryText="Presence or Absence of Measurable Lesions" authors="mcpinho77">
      <Inference annotatorConfidence="false"/>
      <AllowedTerm codeMeaning="Yes" codeValue="RANO7" codingSchemeDesignator="RANO">
      </AllowedTerm>
      <AllowedTerm codeMeaning="No" codeValue="RANO8" codingSchemeDesignator="RANO">
      </AllowedTerm>
      <AllowedTerm codeMeaning="Not Evaluable" codeValue="RANO6" codingSchemeDesignator="RANO">
      </AllowedTerm>
    </Component>
  </Template>
</TemplateContainer>
```

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="1.3.6.1.4.1.25403.879675056567 4.2788.20120109070958.2" 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.

```
<calculationCollection>
  <Calculation cagridId="0" codeMeaning="Length" codeValue="G-A22A" codingSchemeDesignator="SRT" description="Length" uid="1.3.6.1.4.1.25403.8796750565674.2788.20120109070958.1">
    <referencedCalculationCollection/>
    <calculationResultCollection>
      <CalculationResult cagridId="0" numberOfDimensions="1" type="Scalar" unitOfMeasure="mm">
        <calculationDataCollection>
          <CalculationData cagridId="0" value="71.3865693161104">
            <coordinateCollection>
              <Coordinate cagridId="0" dimensionIndex="0" position="0"/>
            </coordinateCollection>
          </CalculationData>
        </calculationDataCollection>
        <dimensionCollection>
          <Dimension cagridId="0" index="0" label="Value" size="1"/>
        </dimensionCollection>
      </CalculationResult>
    </calculationResultCollection>
    <referencedGeometricShapeCollection>
      <ReferencedGeometricShape cagridId="0" referencedShapeIdentifier="0"/>
    </referencedGeometricShapeCollection>
  </Calculation>
</calculationCollection>
```

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="1.3.6.1.4.1.14519.5.2.1.4792.2001.170977198031148408225883336860">
       <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>
     </imageSeries>
    </ImageStudy>
   </imageStudy>
  </ImageReference>
 </imageReferenceCollection>
```

AIM Annotation cont.

```
 <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:

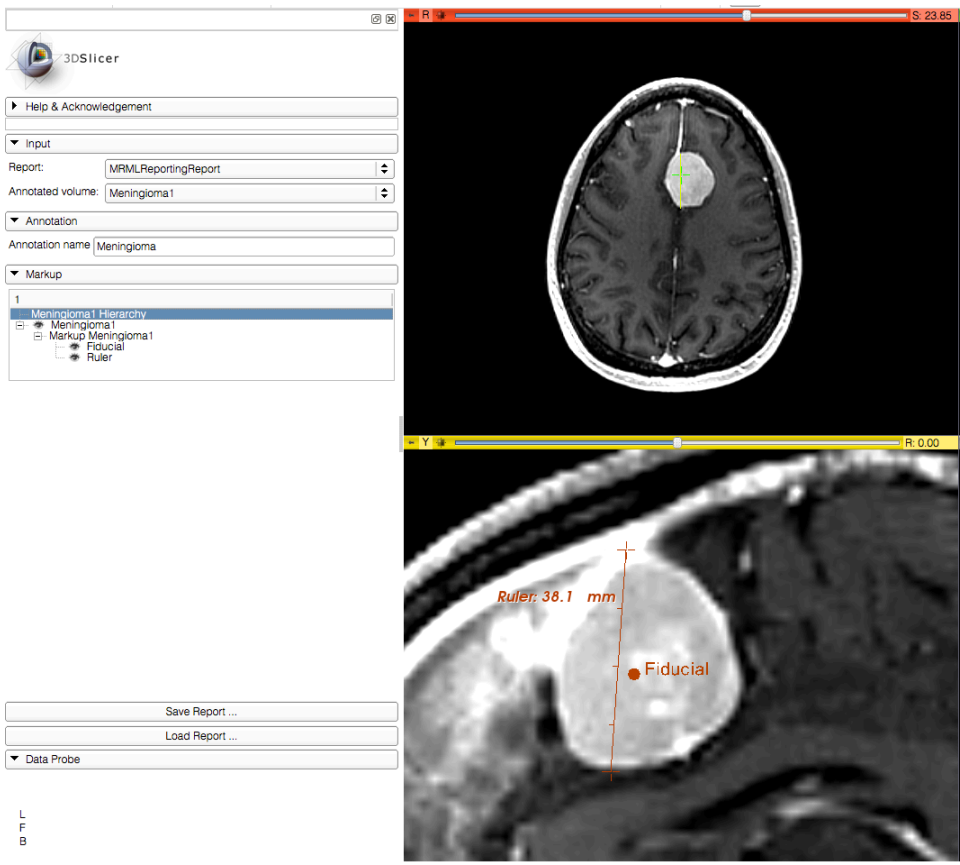
- Research in understanding AIM, DICOM SR, XML
- Development of specialized module in 3D Slicer
- 3D Slicer "book-keeping" infrastructure: Support of tree-based hierarchy for keeping track of markup elements and their relation to the annotated volume
- Internal improvements can also benefit DICOM SR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

Details and status:

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