Announcement

• Final Presentations
  – June 10, 3:30-6:30 in Gates B-03
  – Final project write-ups due June 10 by 11:59pm

Review: Our Data Landscape

1. Images have a rich set of semantic and computational features
2. Representing semantic features (DICOM, AIM, RDF) give these data standard structure and make them machine accessible
3. Machine Learning algorithms help us to make a variety of applications (e.g., classification, prediction, etc.)

Computerized Reasoning

• What is computerized reasoning?
• What is reasoning by query?
• What are methods for image query?
  – String matching on text
  – Query AIM annotations with API
  – Query RDF annotations with SPARQL
• What is decision support?
• What are methods for decision support?

What is computerized reasoning?

Def: Deducing new facts or answers to questions based on domain knowledge and input data (usually images and factual statements) about them

Input data: images, texts, ontologies
• NB: annotated images/texts are crucial
Types of Computer Reasoning

Query: Help me *find* images or text

Decision Support: help me *make decisions* using image data

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Reasoning by Query

- The computer queries a resource based on inputs or information goals to answer a question
- Resources that may be queried:
  - Knowledge representation (an atlas or ontology or data)
  - Images and texts (semantically-annotated)

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Querying Knowledge Representations

- Two kinds of knowledge representations that can be queried:
  - Atlases
  - Ontologies

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When do we query an atlas?

To *transfer knowledge* to your image
Transferring Anatomic Knowledge

ATLAS (each color is a different anatomic region)

PATIENT IMAGE

• What anatomic structure is at point X? Caudate Nucleus

Image Registration

PATIENT IMAGE

• What anatomic structure is adjacent to my anatomic structure at point X? Insula

Pitfalls of atlases

Class Question: What are challenges/pitfalls in using atlases for transferring knowledge to images? (hint: what do you do when you use an atlas to transfer knowledge to the image?)

Encoding atlas info

Class Question: How would you create this atlas (i.e., how would you get the computer to recognize the various anatomic structures in the image map)?

Querying Knowledge Representations

• Two kinds of knowledge representations that can be queried:
  • Atlases
  • Ontologies

When do we query an ontology?

1. Find classes
   • Is “chest” in RadLex?

2. Find attributes values for a given class
   • What are synonyms for “chest”?
   • What is the RadLex ID “chest”?

3. Traverse relations
   • Query expansion
     • E.g., “what are the parts of the chest?”
   • Answer questions
     • E.g., is “astrocytoma” a type of neoplasm?
1. Find Classes

Is “chest” in RadLex?
No “chest”

http://radlex.org

2. Find attribute values for a class

What are synonyms for “chest”?

3. Traverse relations

What is the RadLex ID for “chest” (“thorax”)?

Has-Part hierarchy

Is “glioma” a type of neoplasm?

Quiz

This image is a file's placeholder. Enter slide show mode (FS) to view your poll.
You can resize this image to resize where your poll will load in slide show mode.
Make sure you're installed the PollEveryPresenter app (app.rad lex.org/age) and are connected to the internet!
If you need to download this poll, make sure to copy/paste the entire slide (not just the placeholder image).
### Reasoning by Query

- The computer queries a resource based on inputs or information goals to answer a question.
- Types of resources that may be queried:
  1. **Knowledge representation** (an atlas or ontology or data)
  2. **Images and texts** (semantically-annotated)

### Two places to query images

- Image header
  - Contains image metadata **directly associated with the image**
  - Acquired at the time the image is created
- Image annotations
  - Contains image metadata that are **separate from the images** (e.g., radiology report, image labels added by a reader)
  - Acquired after the image is created

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**Image query:** *Images* as query input

- DICOM images
- NB: Other types of images (e.g., png) lack headers

**Image Query:** *Annotated images* as query input

- Query input
- Matches ontology terms, semantic features, computational features
Quiz

PACS has three DICOM images with following info in “exam type” field:
1. “CT” [RID3]
2. “Computed Tomography Chest” [RID3, RID82]

ANS: 1, 2, and 3

Quiz

PACS with 3 images
- “CT” [RID3]
- “CT Chest” [RID3, RID82]
- “CT Thorax” [RID3, RID82]

Hint: would you query by RID or by string value?

When to use image query?

• Search for images
  • e.g., “Find CT images of the thorax with IV contrast”
  • e.g., “Find images showing a mass in the liver”
• Summarize information in images
  • e.g., “How much is the cancer size changing across multiple CT exams?”
• Make decisions based on images
  • e.g., “Is the patient’s cancer responding well to treatment?”

How do I query?

• Querying DICOM header with text matching
• Query AIM annotations and RDF with SPARQL

How do I query?

• Querying DICOM header with text matching
• Query AIM annotations and RDF with SPARQL
1) Search for images
- e.g., “Find CT images of the thorax with IV contrast”
- How?
  - Perform string matching in fields of the DICOM header...
  - (NB: you need to refer to DICOM standard to know which header fields to search; common ones are “modality” and “study description”)

String matching on DICOM headers
- E.g., how do we find CT images of the thorax with contrast?

Do string matching in DICOM header...
- E.g., how do we find CT images of the thorax with IV contrast?
- Look for “CT” in tag [0008,0060] and “Thorax CHEST_CONTRAST” in [0008,1030]

Querying DICOM files
- DICOM libraries
  - PyDicom (python; code.google.com/p/pydicom/)
  - Pixelmed (java; www.medfloss.org)
  - DCMTK (C++; http://dicom.offis.de/dcmtk.php.en)
- Iterate through DICOM files, grab field values and do string matching

But string matching may not be enough...
- What if we want find “computed tomography images of the chest with IV contrast?”
- NB: you could resolve this using RadLex...

How do I query?
- Querying DICOM header with text matching
- Query AIM annotations and RDF with SPARQL
Motivation for needing to query using RDF or AIM

• AIM and RDF record *semantic information about images* (e.g., anatomy, imaging findings, quantitative image features) separate from the images
• You need a query language to query these formats
  — For RDF: SPARQL
  — For AIM: APIs or XML parsers
• In addition, you can do *computer inference* in addition to simple query

What is SPARQL?

Simple Protocol And RDF Query Language

SPARQL Protocol And RDF Query Language

*Everything represented and queried via triples*

```
("Malcolm Gladwell", "authorOf", "Blink")
```

RDF files (a specialized kind of XML)

What does a query look like?

• SELECT variable(s)
  • Variables: ?x
• FROM clause
  • Identify data sources to query
• WHERE clause
  • The *triple/graph pattern* to match
  • A conjunction of triples

```
SELECT ... FROM ... WHERE { ... }
```

What does a query look like?

*Find the students who are taking BMI260*

```
SELECT ?student
WHERE { ?student sch:hasClass "BMI260" . }
```

Variable names prefixed with “?” or “$”

Statements terminated by “.”

RDF queries are can be thought of as RDF graph traversals

```
SELECT ?student
WHERE { ?student sch:hasClass "BMI260" . }
```

RDF image annotations are “triples”

• Image annotations can be written as RDF triples
• E.g., annotations showing the *imaging observations from liver lesions in Mary Jane*

<table>
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<th>Predicate</th>
<th>Object</th>
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<tbody>
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<td>has ROI</td>
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```
ROI 1
Mary Jane
hasROI
has Anatomic Location

ROI 2
hasROI
has Anatomic Location
```

```
mass-enhancing
mass-irregular
liver
```

```
ROI 1
ROI 2

hasROI
hasROI
```
AIM/RDF annotations are “triples”

- An RDF query can summarize all the imaging observations from the liver lesion in Mary Jane

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PREFIX `rx`: <http://radlex.org/#>

SELECT ?imgobs
WHERE {
  "Mary Jane" `rx:hasROI` ?roi
  ?roi `rx:hasAnatomicLocation"liver"
  ?roi `rx:hasImagingObservation"mass-irregular"
  .
}

Example application using query: Find similar images

- With RDF you can search for other patients who have lesions with the same semantic features (i.e., similar-appearing lesions, content based image retrieval)

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AIM captures annotations in XML

Example application using query:

Find similar images

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Types of Computer Reasoning

Query: Help me find images or text

Decision Support: help me make decisions using image data
What is decision support?

**Decision Support**: a type of computer reasoning that helps to make decisions:

- **Patient diagnosis** (what disease causing the image abnormalities?)
- **Patient treatment selection** (how should we treat the disease?)
- **Treatment response** (is the disease responding to therapy?)

Types of DSS in radiology practice

1. **Computer-assisted diagnosis systems (CAD)**: What/where is the disease?
2. **Treatment response assessment**: Analyze images to determine if patients are responding to treatment

**CAD: What is the disease?**

- Image to be interpreted
- Semantic features
- Computational model
- User interface
- Background knowledge
- Database of cases

**CAD: Where is the disease?**

*Image labeling to deduce structures affected by disease*

- Atlas image (anatomy overlay)
- fMRI image (functional map)*
Types of DSS in radiology practice

1. Computer-assisted diagnosis systems (CAD): What/where is the disease?
2. Treatment response assessment: Analyze images to determine if patients are responding to treatment

Treatment response assessment

How do we make an assessment?

We need: standard criteria for describing the assessment

Response Evaluation of Criteria in Solid Tumors

RECIST CRITERIA

CR = Disappearance of all target lesions
PR = ≥ 30% decrease or more in the SLD of target lesions
PD = ≥ 20% increase or more in the SLD of target lesions
SD = Small changes not meeting above criteria

Methods for Decision Support

- Rule Based
- Statistical/machine learning models
Methods for Decision Support

• Rule Based
• Statistical/machine learning models

Rule Based Methods

INPUT: rules developed by domain experts

FORMAT: IF <pre-conditions> THEN <action>

OUTPUT: a set of **semantic annotations** on text

Automatic classification for response assessment

Patient = Mary Jane hasImage = Image1, Image 2 hasChangeSLD = -36%

AUTOMATIC CLASSIFICATION: Deduces the patient response is PartialResponse (PR)

SEMANTICALLY ANNOTATED DATA

Ontological knowledge with class definitions

Images are represented using feature vectors

Imaging phenotype = quantitative + semantic features

Statistical/machine learning models

• Using **quantitative features**:
  – Many machine learning methods (logistic regression, lasso, SVM etc.)

• Using **qualitative (semantic) features**:
  – Bayesian networks
  – Others machine learning methods could be used too
Statistical/machine learning models

- **Using quantitative features:**
  - Many machine learning methods (logistic regression, lasso, SVM etc.)

- **Using qualitative (semantic) features:**
  - Bayesian networks
  - Others machine learning methods could be used too

### Automated diagnosis using quantitative features

Predicting the type of lung cancer (recurring or non-recurring) using quantitative image texture features

- **What are methods?**
- **What is decision support?**

### Pathology Classification Pipeline

Pathology Classification Pipeline

- **What are some examples?**

### Statistical/machine learning models

- **Using quantitative features:**
  - Many machine learning methods (logistic regression, lasso, SVM etc.)

- **Using qualitative (semantic) features:**
  - Bayesian networks
  - Others machine learning methods could be used too

### A BN for Mammography

- **What are methods?**
What kind of DSS can I make?

- Decision support for biopsy
  - e.g., threshold chance of malignancy $p > 2\% \implies$ biopsy
- Decision support for additional imaging ("diagnostic mammography")
- Opportunity for shared decision-making
- Transparency of basis for decisions

Output probabilities are actionable

What have you learned?

You want to search for MRI images of the brain. What will you search to find them?

- DICOM header
- RDF/AIM annotations
- Radiology reports

What have you learned?

You want to search AIM annotations for images showing pneumothorax, some annotations have this recorded as "pneumothorax," "PTX," or "pneumo." What resource could your query use to retrieve all of these?

What have you learned?

You want to build a decision support system that tells a radiologist the probability that a lung nodule is a cancer based on what they say in their report. What method would be best?
**In summary…**

Computer reasoning deduces new facts or answers questions based on **domain knowledge**, **input images**, and **factual statements** about them.

**What is reasoning by query?**

Reasoning by query is a type of computer reasoning that helps to find images (or text).

**What is reasoning by query?**

We can use **string matching** to query **DICOM headers**, and **SPARQL** to query **RDF** and **AIM**.

**How do I query?**

Decision support systems help make physicians make decisions.

**What is decision support?**

**Rule based** systems and **statistical models** (e.g., Bayesian networks with qualitative features or machine learning with quantitative features) are common and powerful implementations for decision support.
Thank you!