

The Structure of Unstructured Data

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Thanks to

- Professors
 - Dan Lizotte and Hanan Lutfiyya

Today's Topics

- Data format standards associated with “unstructured data”
- Software format standards associated with “unstructured data”

“Structure”?

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“Structure”?

- From Wikipedia “Unstructured Data”, Problems with the term:
 - Structure, while not formally defined, can still be implied.
 - Data with some form of structure may still be characterized as unstructured if its structure is not helpful for the processing task at hand.
 - Unstructured information might have some structure (semi-structured) or even be highly structured but in ways that are unanticipated or unannounced.

“Structure”?

- From OED:
 - 3. a. a. *fig.* The arrangement and organization of mutually **connected** and dependent **elements** in a system or construct.
- **Compositional structure**
 - What useful ways can data be divided into **elements**?
- **Relational structure**
 - What useful ways can elements be **related** to each other?

*Not intended to be mutually exclusive or exhaustive.
There may be lots of other useful ways to define structure!

Examples of structure

- What might be some of the **compositional** and **relational** structure of web pages?
- What might be some of the **compositional** and **relational** structure in google image search results?

Data Standards

- How do we describe the structure of data?
- Considerations for choosing a data standard
 - Flexibility
 - Interoperability
 - Efficiency

Standards: Data Formats

XML

Use iClicker

Who is familiar with XML?

A) Yes

B) No

Standards: Data formats

Thunder and lightning. Enter three Witches

FIRST WITCH

When shall we three meet again
In thunder, lightning, or in rain?

SECOND WITCH

When the hurlyburly's done,
When the battle's lost and won.

XML

```
<?xml version="1.0" encoding="utf-8"?>
<EXCERPT>
<STAGEDIR>Thunder and lightning. Enter three
Witches</STAGEDIR>
<SPEECH>
<SPEAKER ROLE="WITCH">First Witch</SPEAKER>
<LINE>When shall we three meet again</LINE>
<LINE>In thunder, lightning, or in rain?</LINE>
</SPEECH>
<SPEECH>
<SPEAKER ROLE="WITCH">Second Witch</SPEAKER>
<LINE>When the hurlyburly's done,</LINE>
<LINE>When the battle's lost and won.</LINE>
</SPEECH>
</EXCERPT>
```

XML

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<?xml version="1.0" encoding="utf-8"?>
<EXCERPT>
<STAGEDIR>Thunder and lightning. Enter three
Witches</STAGEDIR>
<SPEECH>
<SPEAKER ROLE="WITCH">First Witch</SPEAKER>
<LINE>When shall we three meet again</LINE>
<LINE>In thunder, lightning, or in rain?</LINE>
</SPEECH>
<SPEECH>
<SPEAKER ROLE="WITCH">Second Witch</SPEAKER>
<LINE>When the hurlyburly's done,</LINE>
<LINE>When the battle's lost and won.</LINE>
</SPEECH>
</EXCERPT>
```

What kind of compositional and relational structure does the XML tell us?

XML Rules

Legal Unicode

No syntax chars (e.g. <, &) in content. Use *entities*, e.g. <;, &

Tags cannot overlap, e.g. <A>

Tags are case-sensitive

Tags cannot use special chars or start with digit

There is a single "root" element that contains all the other elements.

```
<?xml version="1.0" encoding="utf-8"?>
```

```
<EXCERPT>
```

```
<STAGEDIR>Thunder and lightning. Enter three Witches</STAGEDIR>
```

```
<SPEECH>
```

```
<SPEAKER ROLE="WITCH">First Witch</SPEAKER>
```

```
<LINE>When shall we three meet again</LINE>
```

```
<LINE>In thunder, lightning, or in rain?</LINE>
```

```
</SPEECH>
```

```
<SPEECH>
```

```
<SPEAKER ROLE="WITCH">Second Witch</SPEAKER>
```

```
<LINE>When the hurlyburly's done,</LINE>
```

```
<LINE>When the battle's lost and won.</LINE>
```

```
</SPEECH>
```

```
</EXCERPT>
```

XML parsing

- XML parsing is the process of converting XML data from its serialized string format to its hierarchical format.
(<https://www.ibm.com/docs/en/db2/10.5?topic=data-xml-parsing>)
- A tree

Parsed XML: A tree

- <EXCERPT>
 - <STAGEDIR>
 - <SPEECH>
 - <SPEAKER ROLE = "WITCH">
 - <LINE>
 - <LINE>
 - <SPEECH>
 - <SPEAKER ROLE = "WITCH">
 - <LINE>
 - <LINE>

XML's evolution

- Primary data format used by IBM
- Used by MS Office as a file format
- HTML5 is valid XML

Questions about XML

- Flexibility
 - What kinds of structure can XML easily describe?
 - What kinds of structure are not easy to describe with XML?
- Interoperability
 - What kinds of interoperability does XML support?
- Efficiency
 - What kinds of operations on data are efficient if XML is used as the data format? What kinds of operations are not efficient?

Standards: Data Formats

JSON

Use iClicker

Who is familiar with JSON?

- A) Yes, I have prior experience
- B) Yes, a little
- C) No

JSON (JavaScript Object Notation)

- JavaScript arrays:
 - `var myarray = ["one", "two", "three"];`
 - Then `myarray[1] == "two"`
- JavaScript objects
 - `var myobject = {firstName:"John", lastName:"Doe"};`
 - Then `myobject.firstName == "John"`

JSON (Javascript Object Notation)

```
{
  "EXCERPT": {
    "STAGEDIR": "Thunder and lightning. Enter three Witches",
    "SPEECH": [
      { "SPEAKER": {
          "ROLE": "WITCH",
          "text": "First Witch"
        }},
      "LINE": [
        "When shall we three meet again",
        "In thunder, lightning, or in rain?"
      ]
    },
    { "SPEAKER": {
        "ROLE": "WITCH",
        "text": "Second Witch"
      }},
      "LINE": [
        "When the hurlyburly's done,",
        "When the battle's lost and won."
      ]
    }
  ]
}
```

JSON (Javascript Object Notation)

```
{
  "EXCERPT": {
    "STAGEDIR": "Thunder and lightning. Enter three Witches",
    "SPEECH": [
      { "SPEAKER": {
          "ROLE": "WITCH",
          "text": "First Witch"
        }},
      { "LINE": [
          "When shall we three meet again",
          "In thunder, lightning, or in rain?"
        ]},
      { "SPEAKER": {
          "ROLE": "WITCH",
          "text": "Second Witch"
        }},
      { "LINE": [
          "When the hurlyburly's done,",
          "When the battle's lost and won."
        ]}
    ]
  }
}
```

What is the value of `myobject.EXCERPT.SPEECH[1].LINE[0]`?

JSON (Javascript Object Notation)

```
{
  "EXCERPT": {
    "STAGEDIR": "Thunder and lightning. Enter three Witches",
    "SPEECH": [
      { "SPEAKER": {
          "ROLE": "WITCH",
          "text": "First Witch"
        }},
      { "LINE": [
          "When shall we three meet again",
          "In thunder, lightning, or in rain?"
        ]},
      { "SPEAKER": {
          "ROLE": "WITCH",
          "text": "Second Witch"
        }},
      { "LINE": [
          "When the hurlyburly's done,",
          "When the battle's lost and won."
        ]}
    ]
  }
}
```

What is the value of `myobject.EXCERPT.SPEECH[1].LINE[0]`?

JSON (Javascript Object Notation)

```
{
  "EXCERPT": {
    "STAGEDIR": "Thunder and lightning. Enter three Witches",
    "SPEECH": [
      { "SPEAKER": {
          "ROLE": "WITCH",
          "text": "First Witch"
        },
        "LINE": [
          "When shall we three meet again",
          "In thunder, lightning, or in rain?"
        ]
      },
      { "SPEAKER": {
          "ROLE": "WITCH",
          "text": "Second Witch"
        },
        "LINE": [
          "When the hurlyburly's done,",
          "When the battle's lost and won."
        ]
      }
    ]
  }
}
```

← How would we reference this value?

*myobj.EXCERPT.SPEECH[0].
SPEAKER.ROLE*

JSON (Javascript Object Notation)

```
{
  "EXCERPT": {
    "STAGEDIR": "Thunder and lightning. Enter three Witches",
    "SPEECH": [
      { "SPEAKER": {
          "ROLE": "WITCH", ← How would we reference this value?
          "text": "First Witch"   myobject.EXCERPT.SPEECH[0].SPEAKER.ROLE
        },
        "LINE": [
          "When shall we three meet again",
          "In thunder, lightning, or in rain?"
        ]
      },
      { "SPEAKER": {
          "ROLE": "WITCH",
          "text": "Second Witch"
        },
        "LINE": [
          "When the hurlyburly's done,",
          "When the battle's lost and won."
        ]
      }
    ]
  }
}
```

JSON's evolution

- Developed for browser \leftrightarrow web server communication of JavaScript objects
- Has become widespread
 - Twitter
 - Reddit
 - ...

Questions about JSON

- Flexibility
 - What kinds of structure can JSON easily describe?
 - What kinds of structure are not easy to describe with JSON?
- Interoperability
 - What kinds of interoperability does JSON support?
- Efficiency
 - What kinds of operations on data are efficient if JSON is used as the data format? What kinds of operations are not efficient?

XML versus JSON

- What do you think are the main differences between using XML versus using JSON?

Json is better in tracking objects;
in Json, keys are linked

- What are the consequences for choosing one over the other?

Data with no standards: system logs

- Jan 11 09:21:14 JRs-MacBook-Pro-2 syslogd[56]: ASL Sender Statistics
- Jan 11 09:21:24 JRs-MacBook-Pro-2 com.apple.xpc.launchd[1] (com.apple.preference.displays.MirrorDisplays): Service only ran for 0 seconds. Pushing respawn out by 10 seconds.
- Jan 11 09:21:38 --- last message repeated 1 time ---
- Jan 11 09:21:38 JRs-MacBook-Pro-2 filecoordinationd[351]: BUG in libdispatch client: kevent[mach_recv] monitored resource vanished before the source cancel handler was invoked
- Jan 11 09:21:44 JRs-MacBook-Pro-2 com.apple.xpc.launchd[1] (com.apple.preference.displays.MirrorDisplays): Service only ran for 0 seconds. Pushing respawn out by 10 seconds.
- Jan 11 09:22:14 --- last message repeated 2 times ---
- Jan 11 09:22:14 JRs-MacBook-Pro-2 com.apple.xpc.launchd[1] (com.apple.preference.displays.MirrorDisplays): Service only ran for 0 seconds. Pushing respawn out by 10 seconds.
- Jan 11 09:22:40 --- last message repeated 2 times ---
- Jan 11 09:22:40 JRs-MacBook-Pro-2 mdworker[811]: mdworker(811,0x700005a2f000) malloc: malloc_memory_event_handler: approaching memory limit. Starting stack-logging.
- Jan 11 09:22:40 JRs-MacBook-Pro-2 mdworker[811]: mdworker(811,0x700005a2f000) malloc: recording malloc (and VM allocation) stacks using lite mode
- Jan 11 09:22:42 JRs-MacBook-Pro-2 mdworker[811]: mdworker(811,0x700005a2f000) malloc: malloc_memory_event_handler: stopping stack-logging
- Jan 11 09:22:42 JRs-MacBook-Pro-2 mdworker[811]: mdworker(811,0x700005a2f000) malloc: turning off recording malloc (but not VM allocation) stacks using lite mode

Standards: Software Components

Standards: Software components

- UIMA – Unstructured Information Management Architecture
 - “Yoo-ee-mah”
- **Software architecture standard**
 - Specifies component interfaces in an analytics pipeline
 - If you write UIMA-compliant software, it can work with other UIMA-compliant software. Like IBM Watson.
 - It suggests two data representations: in-memory for **processing**, XML-based for **communicating**

Unstructured Information Management Applications

- "An unstructured information management (UIM) application may be generally characterized as a software system that analyzes large volumes of unstructured information (text, audio, video, images, etc.) to discover, organize and deliver relevant knowledge to the client or application end-user. An example is an application that processes millions of medical abstracts to discover critical drug interactions. Another example is an application that processes tens of millions of documents to discover key evidence indicating probable competitive threats."
- <http://docs.oasis-open.org/uima/v1.0/uima-v1.0.html>

UIMA's Definition of Unstructured Data

- “Unstructured information may be defined as the **direct product of human communication**. Examples include **natural language documents, email, speech, images and video**. It is information that was **not specifically encoded for machines** to process but rather authored by humans for humans to understand. We say it is “unstructured” because it **lacks explicit semantics** (“structure”) required for applications to **interpret** the information as intended by the human author or required by the end-user application.”
- <http://docs.oasis-open.org/uima/v1.0/uima-v1.0.html>

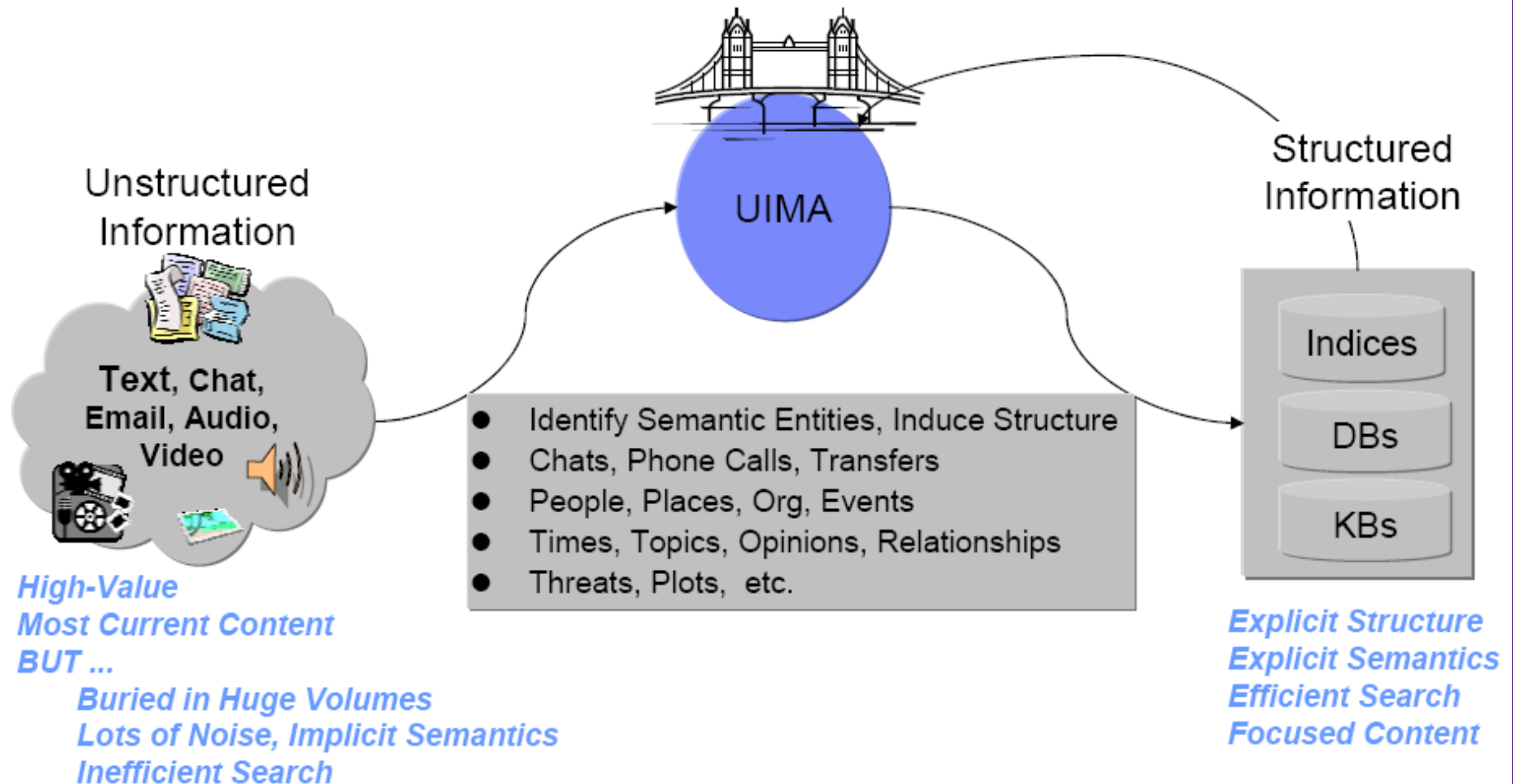
UIMA Definitions

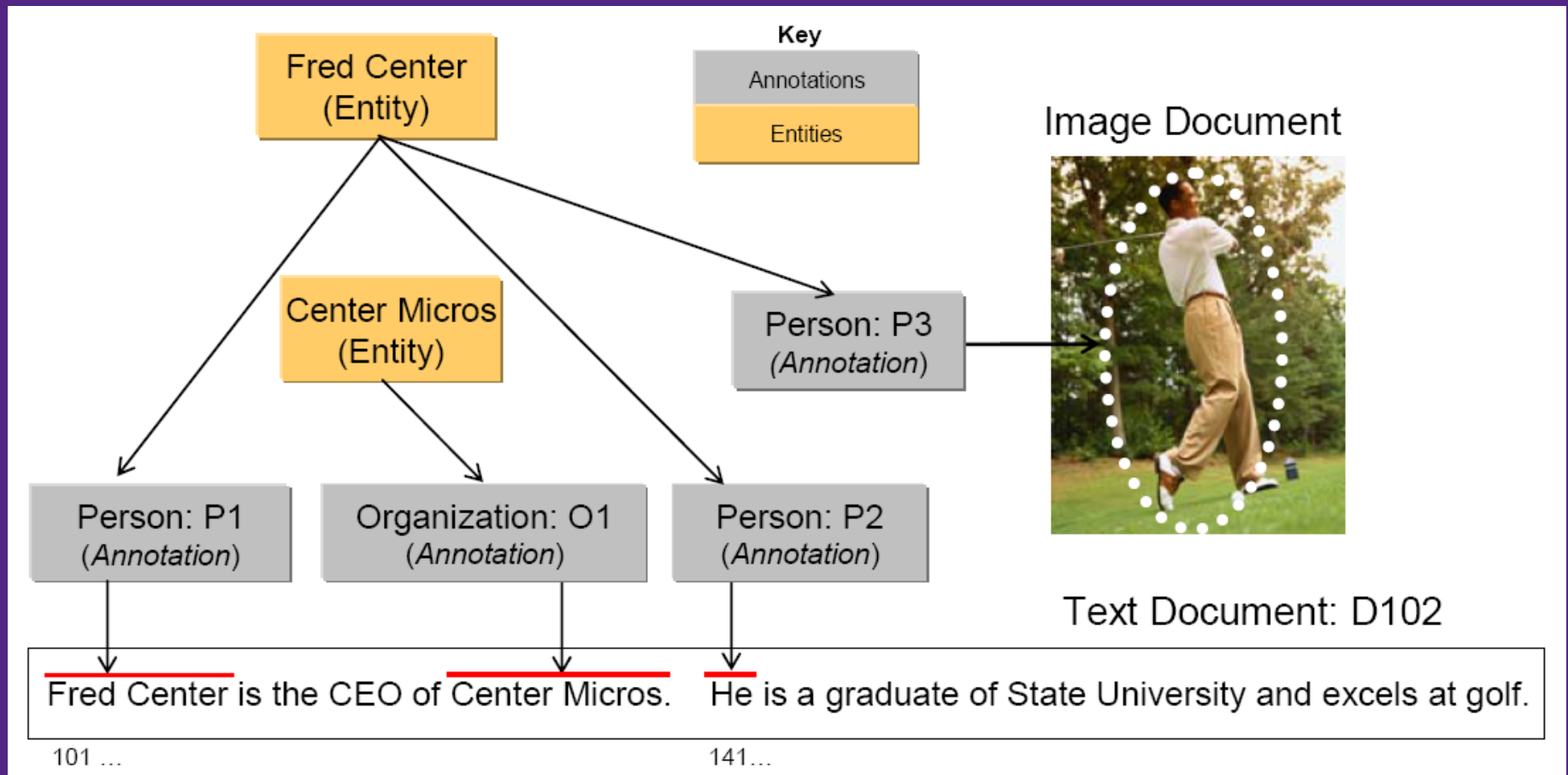
- **artifact** – a segment of unstructured content (e.g., a document, a video etc.)
- **analysis** – act of assigning semantics to a region of an artifact
- **analytic (or Analysis Engine [AE])** – software component or service that performs the analysis
- **artifact metadata** – results of the **analysis** of an **artifact** by an **analytic**

UIMA Analytics

- Analytics are typically **reused** and **combined** to perform application-specific analyses
- For example:
 - first analytic identifies distinct words in a document
 - second analytic identifies parts of speech (verb, noun, ...)
 - third analytic uses the output of the previous two to identify instances of persons, organizations and the relationships between them

Analytics bridge the Unstructured & Structured worlds





UIMA defines building blocks called **Analysis Engines (AEs)**.

One way to think about AEs is as software agents that automatically discover and record *meta-data* about original content, e.g.:

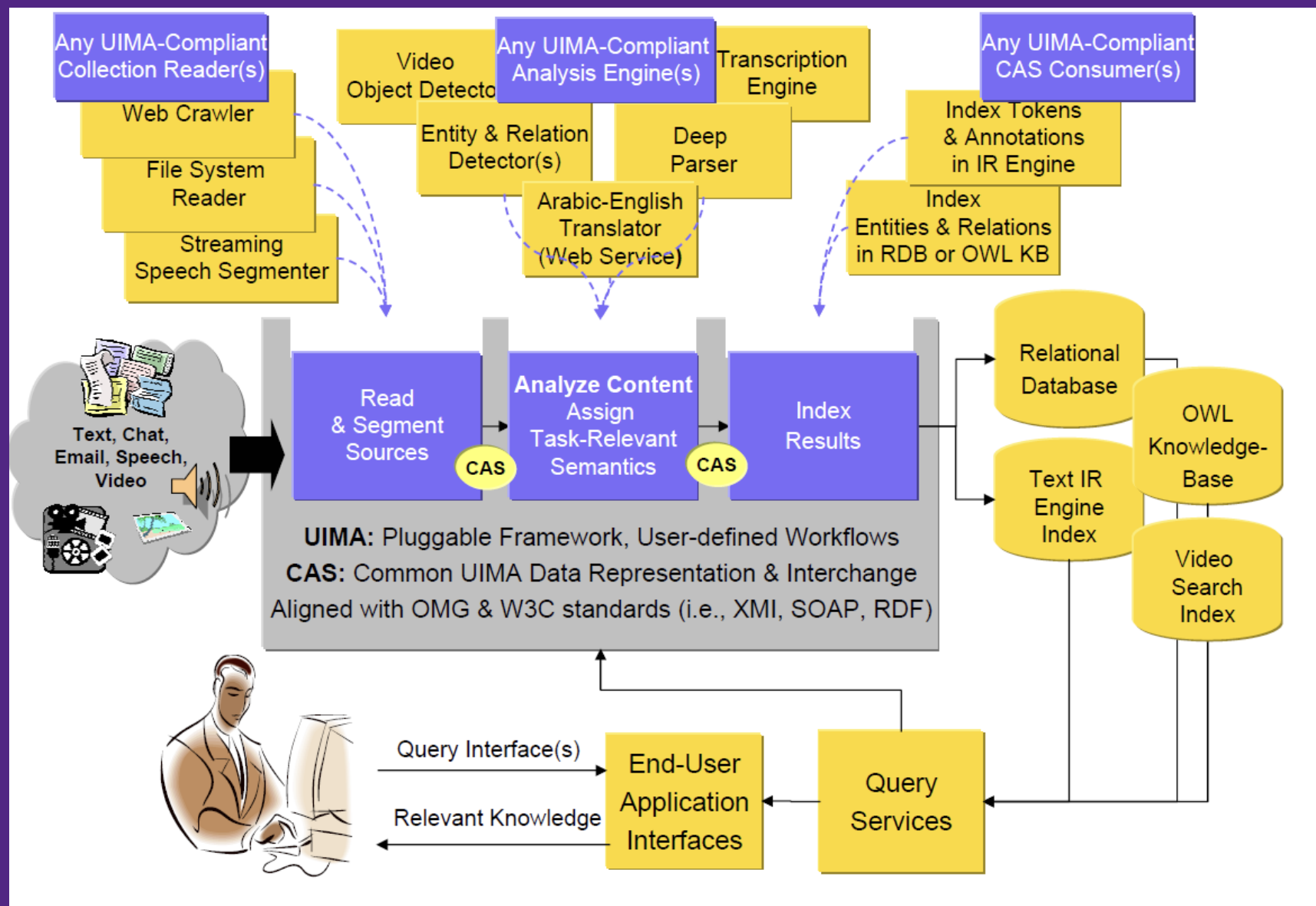
- (1) The Topic of document D102 is "CEOs and Golf".
- (2) The span from position 101 to 112 in document D102 denotes a Person
- (3) The Person denoted by span 101 to 112 and the Person denoted by span 141 to 143 in document D102 refer to the same Entity.

UIMA-based systems

- [IBM Research](#)'s [Watson](#) uses [UIMA](#) for standardizing how it processes data.
- The Clinical Text Analysis and Knowledge Extraction System ([Apache cTAKES](#)) is a UIMA-based system for information extraction from medical records.
- [DKPro Core](#) is a collection of reusable UIMA components for general-purpose natural language processing.

UIMA Implementation

- Common Analysis Structure (CAS): Container for Data Structures in user-defined data model
 - (which can be defined in UML)
- Annotator (analysis engine): Pluggable component (Java or C++, among others) that reads and writes a CAS
- Aggregate Analysis Engine: Collection of Annotators
- The Common Analysis Structure (CAS) is an object-based data structure. It logically contains the documents to be analyzed. Analysis engines present and share their results in a CAS. With CAS, you can represent objects, properties, and values. (<https://www.ibm.com/docs/en/db2/10.1.0?topic=concepts-common-analysis-structure>)



Why a standard?

- EXAMPLE: find all telephone numbers in running text
Regular expression: `[0-9]{3} -? [0-9]{4}`
- Idea: in-line annotations, e.g., modify text
 - “Call Jenny; her number is *PHONE*867-5309*PHONE*.”
- Gets very messy very quickly:
 - “*VERB*Call*VERB**NOUN**PERSON*Jenny*PERSON*NOUN*; *PRONOUN*her*PRONOUN*
*NOUN**SUBJECT*number*SUBJECT**NOUN* is
*PHONE*867-5309*PHONE*.”
- Makes the next component of the pipeline’s job a total pain; discourages software re-use.

UIMA Idea:

“Standoff Annotations”

- Keep original text
- Add annotations with associated offsets in the original text
- “Call Jenny; her number is 867-5309.”
- Phone number annotation: (27,34)

UIMA Idea: “Type Systems”

```
...<boilerplate>...  
<typeDescription>  
  <name>org.apache.uima.tutorial.RoomNumber</name>  
  <supertypeName>uima.tcas.Annotation</supertypeName>  
  <features>  
    <featureDescription>  
      <name>building</name>  
      <description>Building containing this room</description>  
      <rangeTypeName>uima.cas.String</rangeTypeName>  
    </featureDescription>  
  </features>  
</typeDescription>  
...<boilerplate>
```

Example Analysis Engine Code

```
private Pattern myPattern = Pattern.compile("\\b[0-4]\\d-[0-2]\\d\\d\\b");
public void process(JCas aJCas) { //Pass in Common Analysis Structure
    // get document text
    String docText = aJCas.getDocumentText();
    // search for room numbers
    Matcher matcher = myPattern.matcher(docText);
    int pos = 0;
    while (matcher.find(pos)) {
        // found one - create annotation
        RoomNumber annotation = new RoomNumber(aJCas);
        annotation.setBegin(matcher.start());
        annotation.setEnd(matcher.end());
        annotation.setBuilding("Yorktown");
        annotation.addToIndexes();
        pos = matcher.end();
    }
}
```

Optional: https://uima.apache.org/d/uimaj-current/tutorials_and_users_guides.html

Example Annotations

The screenshot displays the UIMA Annotation Viewer interface. The main text area contains a report from March 2003 about Robert Crane and Gorman Food Importers Inc. The text is annotated with various semantic entities. A legend at the bottom left shows categories like Person, Facility, GPE, Organization, GeneralStaff, BasedIn, and Management, each with a corresponding colored box. A detailed view on the right shows the structure of the 'Organization' entity, including its begin/end positions, componentId, and mentionType. A yellow callout box labeled 'A CAS' points to the annotations in the text and the legend, listing three key features: analyzed by a combination of Analysis Engines, semantic entities & relations represented, and highlighted in a GUI.

UIMA Annotation Viewer

Report Date 10 March 2003. Slick business dealings keep local olive oil importer out of the pits. Robert Crane was recognized by local business leaders for his skill at leading the Gorman Food Importers Inc. to strong profits while others are struggling. Mr. Crane, owner of Gorman Food Importers Inc., has consistently been able to produce exceptional results, while still keeping a focus on his employees. Gorman Food Importers Inc. has been in business since 1970 and specializes in food imports from the Middle East, including olive oil and figs. Gorman Food Importers Inc. is headquartered in NYC, and their warehouse is located in Paramus, NJ. The company employs 659 people in the two locations. Robert Crane can be reached at 608-703-2317.

Click In Text to See Annotation Detail

- Organization ("Gorman Food Importers Inc.")
 - begin = 185
 - end = 211
 - componentId = ACE
 - mentionType = NAME
- Organization ("Gorman Food Importers Inc.")
 - begin = 185
 - end = 211
 - componentId = IBMEAnnotator
 - mentionType = NAME

Legend

<input checked="" type="checkbox"/> Person	<input checked="" type="checkbox"/> Facility	<input checked="" type="checkbox"/> GPE	<input checked="" type="checkbox"/> Organization
<input checked="" type="checkbox"/> GeneralStaff	<input checked="" type="checkbox"/> BasedIn	<input checked="" type="checkbox"/> Management	

Select All Deselect All Viewer Mode: ☒ Annotations

A CAS

- Analyzed by a combination of Analysis Engines
- Semantic Entities & Relations Represented
- Highlighted here in a GUI

Watson on Jeopardy!



UIMA Questions

- Can you describe an application that we haven't discussed that would benefit from a UIMA architecture?
- Can you think of an application for which UIMA would *not* be a good choice of software standard? Why not?

Summary

- Types of structure
 - **Compositional** and **relational**
- Formats for unstructured data
 - XML
 - JSON
- Software standards
 - UIMA; "annotation-centred" view of unstructured data analysis