Predicate Argument Structure Frames for Modeling Information in Operative Notes

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Aug, 22, 2013
Introduction

- Surgery is a branch of medicine - treatment of injuries or disorders of the body by incision or manipulation.

- Operative procedures are highly stressful, costly, and impactful healthcare event.
  - 45 million surgeries annually in USA in an increasingly elderly population.
  - Need for quality improvement in surgical care to improve outcomes and efficiencies.

- Clinical surgical research – examines the factors including operative factors (e.g., incision length, mesh type, technique) affecting surgical outcomes.
Introduction

Operative notes – document surgical procedures

**PREOPERATIVE DIAGNOSIS:** Gallstone pancreatitis.

**POSTOPERATIVE DIAGNOSIS:** Gallstone pancreatitis.

**PROCEDURE:** Laparoscopic cholecystectomy with cholangiogram. Umbilical hernia repair.

**ANESTHESIA:** General endotracheal anesthesia.

**INDICATIONS:** The patient is a 52-year-old gentleman who presented to the hospital with signs and symptoms consistent with gallstone pancreatitis. His lipase has come down to normal and his Coumadin has been held. His INR this morning is 1.4.

**PROCEDURE DESCRIPTION:** Mr. XXX was brought to the operating room and placed on the operating table in the supine position. General anesthesia was induced without complication. The area over his anterior abdomen was prepped and draped in usual sterile fashion........
Introduction

Procedure description section -

“Mr. XXX was brought to the operating room and placed on the operating table in the supine position. General anesthesia was induced without complication. The area over his anterior abdomen was prepped and draped in usual sterile fashion. Approximately a 3 cm curvilinear incision was made inferior to the umbilicus. This was carried through the skin and subcutaneous tissues until the anterior abdominal wall fascia was identified...”
Introduction

Approximately a 3 cm curvilinear incision was made inferior to the umbilicus.

- What: a 3 cm curvilinear Incision
- Action: make
- Where: inferior to the umbilicus

This was carried through the skin and subcutaneous tissues until the anterior abdominal wall fascia was identified.

- What: 3 cm curvilinear Incision
- Action: carry
- Path: through the skin and subcutaneous tissues
- Extent: until the anterior abdominal wall fascia was identified
Once this wide elevation was done, I incised through the septum with a septal scissors to remove the central part of the cartilage.

**Predicate Argument Structure (PAS) frame**
- A collection of *core semantic arguments*
  of a predicate

<table>
<thead>
<tr>
<th>Predicate: Incise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carver, Surface carved</td>
</tr>
<tr>
<td>Instrument, Time, Purpose</td>
</tr>
</tbody>
</table>

Once this wide elevation was done, I incised through the septum with a septal scissors to remove the central part of the cartilage.
Background

- Proposition Bank ("PropBank")
  - Resource of verb frames
  - 3,324 frame files

Roleset id: incise.01, cut, carve

- **Arg0**: carver
- **Arg1**: surface carved
- **Arg2**: thing created on the surface

Background

- Action verbs in operative notes
  - May have additional special meanings
  - May utilize different semantic arguments from general English

- PropBank - 85% coverage of action verb senses used in operative notes

Background

Natural Language Processing to detect the semantic arguments associated with the predicate or verb of a sentence and their classification into their specific roles.

We dissected out the cystic artery

Predicate

Agent: We

Dissected: dissected

Out the cystic artery: PP

Thing being dissected: NP
Objective

- Create Predicate Argument Structure (PAS) frames for frequent operative note action verbs
  - Utilize PropBank resource
  - Compare operative note frames to general English frames in PropBank
Methods

- Overview

  - Top Action Verb Selection
  - Development: PropBank-style PAS Frames
  - Evaluation: Validation of PAS Frames
Methods

- Top action verb selection

All Operative notes (2002-2008) of Fairview Health Services

Pre-process Pipeline

- Section extraction
- Sentence splitting
- Deep parsing

Top 30 action verbs
Methods

- PAS frame development

- 3,000 Notes: Laparoscopic Cholecystectomy
  - ICD-9-CM 51.23

Pre-process Pipeline

- Section extraction ➔ Sentence splitting ➔ Deep parsing ➔ Verb normalization
- Sample selection
- PAS creation ➔ PAS for 30 verbs
  - 40 samples per verb
Methods

- Creation of PropBank style PAS
  - Verb senses collection
    - “The patient left the operating room.”
    - “2 pieces of Surgicel were left in this area.”
  - Core argument evaluation
    - Based on usage with each verb sense
    - (Arg0, Arg1, ... ArgM) definition
Methods

- PAS frames for 30 verbs (40 samples each)

<table>
<thead>
<tr>
<th>Action verb: Close</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roleset id: close.01, shut</td>
</tr>
<tr>
<td>Arg0: person doing the closing</td>
</tr>
<tr>
<td>Arg1: thing closing</td>
</tr>
<tr>
<td>Arg2: anti-beneficiary</td>
</tr>
<tr>
<td>Arg3: manner</td>
</tr>
</tbody>
</table>

Examples in operative notes:

1. The fascia at the umbilical incision was **closed** with interrupted 2-0 Vicryl sutures.

   Rel: closed
   Arg1: The fascia at the umbilical incision
   **Arg3: with interrupted 2-0 Vicryl sutures**
Methods

- Validation

- 30 verbs – 10 samples/procedure
  - Right Colectomy ICD-9-CM 45.73
  - Transverse Colectomy ICD-9-CM 45.74
  - Left Colectomy ICD-9-CM 45.75
  - Sigmoid Colectomy ICD-9-CM 45.76
  - Low Anterior Resection ICD-9-CM 48.63
  - Misc Colorectal proc ICD-9-CM 45.7-9

Pre-process Pipeline:
- Section extraction
- Sentence splitting
- Deep parsing

Verb normalization
Sample selection

PAS Evaluation
PAS for 30 verbs
Results

- 40 senses collected for 30 action verbs

**PropBank-Style PAS Frames**

- 65% (26) Same as in PropBank
- 27.50% (11) Modified
- 7.50% (3) New sense
Results

- New sense (example)

<table>
<thead>
<tr>
<th>Action verb: Clip</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roleset id: clip.m01, to fasten, hold tight</td>
</tr>
<tr>
<td>Arg0: entity performing clipping</td>
</tr>
<tr>
<td>Arg1: thing being clipped</td>
</tr>
<tr>
<td>Arg2: location clipped</td>
</tr>
<tr>
<td>Arg3: instrument</td>
</tr>
</tbody>
</table>

**Example in operative note:**

1. The cystic duct was *clipped* proximally with a laparoscopic clipping device and divided.
   - Rel: clipped
   - Arg1: cystic duct
   - Arg2: proximally
   - Arg3: laparoscopic clipping device
Results

- Modified frame

**Action verb: Divide**

Roleset id: divide.02, separate
- Arg0: entity causing separation
- Arg1: thing being divided
- Arg2: divided among/between, if separate from arg1
- **Arg3: instrument**

**Examples in operative notes:**

1. The distal duodenum was *divided with the GIA stapler*.
2. The artery was doubly clipped proximally and *divided with a Harmonic scalpel*. 
Results

- Modified frame

<table>
<thead>
<tr>
<th>Action verb: Irrigate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roleset id: irrigate.01</td>
</tr>
<tr>
<td>Arg0: provider of water</td>
</tr>
<tr>
<td>Arg1: recipient of water</td>
</tr>
<tr>
<td>Arg2: material</td>
</tr>
</tbody>
</table>

Examples in operative notes:

1. Then the peritoneal cavity was thoroughly *irrigated with normal saline*.
2. I thoroughly *irrigated with antibiotic solution*. 
Results - validation

- Coverage of 40 senses

<table>
<thead>
<tr>
<th>Surgery Type</th>
<th>Total Senses</th>
<th>Senses Not Covered</th>
<th>Sense Coverage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right Colectomy</td>
<td>38</td>
<td>0</td>
<td>100.00%</td>
</tr>
<tr>
<td>Transverse Colectomy</td>
<td>38</td>
<td>0</td>
<td>100.00%</td>
</tr>
<tr>
<td>Left Colectomy</td>
<td>36</td>
<td>1</td>
<td>97.22%</td>
</tr>
<tr>
<td>Sigmoid Colectomy</td>
<td>36</td>
<td>0</td>
<td>100.00%</td>
</tr>
<tr>
<td>Lower Anterior Resection</td>
<td>36</td>
<td>0</td>
<td>100.00%</td>
</tr>
<tr>
<td>Miscellaneous Colorectal Proc</td>
<td>39</td>
<td>1</td>
<td>97.44%</td>
</tr>
</tbody>
</table>

- PAS evaluation of 40 senses
  - 100% coverage of PAS core arguments
Conclusion

- Differences between general English PropBank frames and operative note PAS-style frames
- Good agreement in the frames created from a development group of operative notes
  - Excellent coverage of action verb usage in colorectal gastrointestinal operative notes
- Further work to validate our findings with larger operative note corpora
Acknowledgements

- UMN NLP/IE Program
- University of Minnesota Institute for Health Informatics Seed Grant
- National Library of Medicine (R01 LM009623-01)
- Fairview Health Services

Road to the Future (Harris Gulko)