The Robotic Surgery Procedural Framebank

Marco Bombieri¹, Marco Rospocher¹, Simone Paolo Ponzetto², Paolo Fiorini¹

1. University of Verona
2. University of Mannheim
Abstract

Robot-Assisted minimally invasive surgery

Described in:

Tons of books and academic papers

Contain:

Surgical Procedural Knowledge

We need:

Development of clinical decision support systems
Development of automation methods for some steps

Useful for:

Robotic Surgery Procedural Framebank (RSPF)
A lot of procedural surgical texts

Surgical procedural knowledge: the one possessed by an intelligent agent able to perform a task.

“After the dissection of the hilar vessels Gerota’s fascia is incised to expose the tumor.”

Actions, instruments, surgical technique, anatomical parts, spatial or temporal attributes, purpose, ...

“The renal fascia separates the adipose capsule of kidney from the overlying parental fat.”

Surgical procedural knowledge

Surgical non-procedural knowledge

‘How to do a partial nephrectomy?’
Procedural surgical NLP applications

- Improving situation awareness modules
- Developing knowledge-based decision-making techniques
- Summarization systems
- Automatic generation of procedural guidelines
- Drafting safety checklist

- Semantic Role Labeling (SRL)
- Lexical resources
- PropBank
- FrameNet

Frames in general-English are different from the ones of surgery

Robotic Surgery Procedural Framebank (RSPF)
PropBank coverage for the robotic-surgical domain

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
<th>Coverage SPKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present</td>
<td>PB has a frame file that adequately describes the use of the predicate</td>
<td>∼41% in SPKS</td>
</tr>
<tr>
<td>Missing Role</td>
<td>PB has a frame for the predicate, but does not include domain-specific</td>
<td>∼36% in SPKS</td>
</tr>
<tr>
<td></td>
<td>semantic roles often used in our domain.</td>
<td></td>
</tr>
<tr>
<td>Missing Frame</td>
<td>The lemma is already present in PB, but a proper frame is missing as the</td>
<td>∼21% in SPKS</td>
</tr>
<tr>
<td></td>
<td>existing ones describe different meanings.</td>
<td></td>
</tr>
<tr>
<td>Missing Lemma</td>
<td>The lemma is not present in PB.</td>
<td>∼2% in SPKS</td>
</tr>
</tbody>
</table>

PropBank coverage for the robotic-surgical domain

Method 1

Method 2

Verbs

Nominalized-verbs

SPKS Dataset

PRESENT?

MISSING_ROLE?

MISSING_FRAME?

MISSING_LEMMA?
Method 1. Harvesting frame-evoking verbs

Robot-assisted surgery texts

Search Algorithm & Frequency Analysis

OntoNotes Corpus

Actions Extraction Algorithm

Grasp Dissect Kocherize Spatulate ...

Frequency Analysis

- Grasp  \( \text{freq}_1 \)
- Dissect  \( \text{freq}_2 \)
- Kocherize  \( \text{freq}_3 \)
- Spatulate  \( \text{freq}_4 \)
- ...
  \( \text{freq}_N \)

Linguistic experts analyze each verb \((v_i)\)
Method-2. Harvesting frame-evoking nouns

In medical English, a lot of actions are expressed using nouns rather than verbs.

- At this point a **sutura
tion** of the vein is carried out
- The **exposure** of renal hilum is now performed
- ...

Unsupervised keyword extraction problem

Filtering out words ending with specific suffixes*

Manual revision

Linguistic experts analyze each noun

*suffixed analysed: -sion, -son, -tion, -ment, -ery, -ence, -ance, -ure, -ize, -ify*
Framing of domain-actions

Linguistic experts analyze each action

- **Verbs**
- **Nominalized-verbs**

Lemmas Analysis

- **PRESENT**
  - No changes
- **MISSING_LEMMA**
  - New lemma, frame and roles
- **MISSING_FRAME**
  - New frame and roles
- **MISSING_ROLES**
  - New roles

Surgeon validation*

RSPF

*of some lemmas
### Verbs and nouns describing actions – examples

<table>
<thead>
<tr>
<th>Action</th>
<th>Modification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extraperitonealize</td>
<td>MISSING_LEMMA</td>
</tr>
<tr>
<td>Resect</td>
<td>MISSING_ROLE</td>
</tr>
<tr>
<td>Spatulate</td>
<td>MISSING_LEMMA</td>
</tr>
<tr>
<td>Skeletonize</td>
<td>MISSING_LEMMA</td>
</tr>
<tr>
<td>Kocherize</td>
<td>MISSING_LEMMA</td>
</tr>
<tr>
<td>Insufflate</td>
<td>MISSING_LEMMA</td>
</tr>
<tr>
<td>Redock</td>
<td>MISSING_LEMMA</td>
</tr>
<tr>
<td>Detubularize</td>
<td>MISSING_LEMMA</td>
</tr>
<tr>
<td>Grasp</td>
<td>MISSING_FRAME</td>
</tr>
<tr>
<td>Incise</td>
<td>MISSING_ROLE</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Action</th>
<th>Ref. Verb</th>
<th>Modification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Placement</td>
<td>Place</td>
<td>PRESENT</td>
</tr>
<tr>
<td>Reflection</td>
<td>Reflect</td>
<td>MISSING_FRAME</td>
</tr>
<tr>
<td>Retraction</td>
<td>Retract</td>
<td>MISSING_ROLE</td>
</tr>
<tr>
<td>Resection</td>
<td>Resect</td>
<td>MISSING_ROLE</td>
</tr>
<tr>
<td>Mobilization</td>
<td>Mobilize</td>
<td>MISSING_FRAME</td>
</tr>
<tr>
<td>Exposure</td>
<td>Expose</td>
<td>PRESENT</td>
</tr>
<tr>
<td>Traction</td>
<td>---</td>
<td>MISSING_LEMMA</td>
</tr>
<tr>
<td>Administration</td>
<td>Administer</td>
<td>PRESENT</td>
</tr>
<tr>
<td>Identification</td>
<td>Identify</td>
<td>MISSING_FRAME</td>
</tr>
<tr>
<td>Excision</td>
<td>Excise</td>
<td>MISSING_ROLE</td>
</tr>
</tbody>
</table>
Some examples

<frameset>
<predicate Lemma="skeletonize.01">
<roleset id="skeletonize.01">
  name="the stripping of serosal tissues from certain structures, e.g., the round ligament, fallopian tube, to facilitate clamping or excision and minimize bleeding."/>
<note>Frames file for 'skeletonize' based on a definition given by "Concise Dictionary of Modern Medicine"</note>
<roles>
  <role descr="agent" f="" n="0"/>
  <role descr="anatomical part skeletonized" f="" n="1"/>
</roles>
<example name="skeletonize - surgery" src="" type="">
  <text>The uterine vessels are then carefully skeletonized.</text>
  <arg f="" n="1">The uterine vessels</arg>
  <arg f="" n="m">carefully</arg>
</example>
</roleset>
</predicate>
</frameset>
Some examples

<frameset>
  <predicate Lemma="retract">
    <roleset id="retract.01" name="to take back.">
      <aliases>[...]</aliases>
      <roles>
        <role descr="taker back, agent" f="PAG" n="0">
          <vnode vrcls="10.1" vtheta="Agent"/>
        </role>
        <role descr="thing retracted" f="PPT" n="1">
          <vnode vrcls="18.1" vtheta="Theme"/>
        </role>
      </roles>
    </roleset>
  </predicate>
</frameset>

<!--ADDED-->

<example name="Surgery with arg2 and arg4" src="" type=""/>
  <text>The mediastinal pleura is then retracted posteriorly with cadiere forceps (arm 3).</text>
  <arg f="" n="1">The mediastinal pleura</arg>
  <arg f="" n="m">then</arg>
  <rel f=""/>retracted</rel>
  <arg f="" n="4">posteriorly</arg>
  <arg f="" n="2">with cadiere forceps (arm 3)</arg>
</example>

<example name="Surgery with arg3" src="" type=""/>
  <text>The left lobe of the liver can easily be retracted using the suture-gauze liver suspension method.</text>
  <arg f="" n="1">The left lobe of the liver</arg>
  <rel f=""/>retracted</rel>
  <arg f="" n="3">using the suture-gauze liver suspension method</arg>
</example>

<!--ADDED-->

<example name="Surgery with arg2 and arg4" src="" type=""/>
  <text>The mediastinal pleura is then retracted posteriorly with cadiere forceps (arm 3).</text>
  <arg f="" n="1">The mediastinal pleura</arg>
  <arg f="" n="m">then</arg>
  <rel f=""/>retracted</rel>
  <arg f="" n="4">posteriorly</arg>
  <arg f="" n="2">with cadiere forceps (arm 3)</arg>
</example>

<!--ADDED-->

<example name="Surgery with arg3" src="" type=""/>
  <text>The left lobe of the liver can easily be retracted using the suture-gauze liver suspension method.</text>
  <arg f="" n="1">The left lobe of the liver</arg>
  <rel f=""/>retracted</rel>
  <arg f="" n="3">using the suture-gauze liver suspension method</arg>
</example>

<!--ADDED-->

<example name="Surgery with arg2 and arg4" src="" type=""/>
  <text>The mediastinal pleura is then retracted posteriorly with cadiere forceps (arm 3).</text>
  <arg f="" n="1">The mediastinal pleura</arg>
  <arg f="" n="m">then</arg>
  <rel f=""/>retracted</rel>
  <arg f="" n="4">posteriorly</arg>
  <arg f="" n="2">with cadiere forceps (arm 3)</arg>
</example>

<!--ADDED-->

<example name="Surgery with arg3" src="" type=""/>
  <text>The left lobe of the liver can easily be retracted using the suture-gauze liver suspension method.</text>
  <arg f="" n="1">The left lobe of the liver</arg>
  <rel f=""/>retracted</rel>
  <arg f="" n="3">using the suture-gauze liver suspension method</arg>
</example>

<!--ADDED-->

<example name="Surgery with arg2 and arg4" src="" type=""/>
  <text>The mediastinal pleura is then retracted posteriorly with cadiere forceps (arm 3).</text>
  <arg f="" n="1">The mediastinal pleura</arg>
  <arg f="" n="m">then</arg>
  <rel f=""/>retracted</rel>
  <arg f="" n="4">posteriorly</arg>
  <arg f="" n="2">with cadiere forceps (arm 3)</arg>
</example>

<!--ADDED-->

<example name="Surgery with arg3" src="" type=""/>
  <text>The left lobe of the liver can easily be retracted using the suture-gauze liver suspension method.</text>
  <arg f="" n="1">The left lobe of the liver</arg>
  <rel f=""/>retracted</rel>
  <arg f="" n="3">using the suture-gauze liver suspension method</arg>
</example>
The Robotic Surgery Procedural Framebank

252 analyzed lemmas
The Robotic Surgery Procedural Framebank

<table>
<thead>
<tr>
<th>Category</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARG-0</td>
<td>44</td>
</tr>
<tr>
<td>ARG-1</td>
<td>46</td>
</tr>
<tr>
<td>MNR./TECH.</td>
<td>36</td>
</tr>
<tr>
<td>INSTR.</td>
<td>30</td>
</tr>
<tr>
<td>WHERE</td>
<td>22</td>
</tr>
<tr>
<td>THROUGH</td>
<td>9</td>
</tr>
<tr>
<td>ST. PT.</td>
<td>2</td>
</tr>
<tr>
<td>END. PT.</td>
<td>4</td>
</tr>
<tr>
<td>OTHER SP. ATT.</td>
<td>32</td>
</tr>
<tr>
<td>PURPOSE</td>
<td></td>
</tr>
<tr>
<td>OTHER</td>
<td>13</td>
</tr>
</tbody>
</table>
The Robotic Surgery Procedural Framebank

- Who performs the action?
- Anatomical part that undergoes the action
- Instrument used
- Surgical technique
- Purpose
- Spatial information

Surgical Procedural Language
Conclusions

PropBank extension

Keyword extraction method

Frequency comparison method

Framing of RSPF

Robotic Surgery Procedural Framebank
Future works

- Annotating domain-specific texts with SRL information
- Investigate the benefit of training/fine-tuning using domain specific annotations
- Benchmark the coverage and quality of SOTA systems
Thanks for the attention!

E-MAIL: marco.bombieri_01@univr.it

WEB-SITE: https://gitlab.com/altairLab/robotic-surgery-propositional-bank