Digital Therapy Models for Clinical Decision Support

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Outline

• Decision support scenario
• Competing approaches
• The DPM approach
• Deployment in the clinic

Slide acknowledgements: Mario A. Cypko
Decision Support Scenario
Scenario: Laryngeal Cancer Treatment
Tumor Board Meetings for Clinical Decision Making in Laryngeal Cancer Treatment
Competing Approaches to Supporting Clinical Decision Making
Competing Approaches

Data-driven Learning

- Integration of ML, NLP, information retrieval, knowledge representation, and automated reasoning
- Require huge amounts of high-quality (patient) data
- Reasoning of algorithms hard to understand
- Example: IBM Watson for Oncology [IBM2018]

Knowledge-driven Modelling

- Explicit organization, modelling and integration of available knowledge from various sources
- Require expert modelers and update mechanisms
- Reasoning of algorithms is easy to understand
- Example: Warfarin therapy [Yet2013]
The DPM Approach: Knowledge-Driven Bayesian Network Modelling
The DPM Approach: Bayesian Network Modelling
Bayesian Network in a Nutshell

Graphical Modelling example of laryngeal cancer

Source: https://www.youtube.com/watch?v=Ft2tSwSoNuY
Bayesian Network in a Nutshell

Probabilistic Modelling example of laryngeal cancer

Source: https://www.youtube.com/watch?v=Fl2tIwSoNuY
Bayesian Network in a Nutshell

Inferencing

Source: https://www.youtube.com/watch?v=Fl2tlwSoNuY
Modeling BN Structure
Treatment Decision Model for Laryngeal Cancer [Stoehr2014]

Three years of teamwork of one clinician and one engineer (+ expert meetings):
First year, every day full time, second year, twice a week for four hours,
third year, once a week for four hours
Expert-Friendly Structure Modeling
[Cypko2017c]

Modelling workflow

Development of a web-based tool for BN graph modeling

In collaboration with:

Freie Universität Berlin
Modeling BN Parameters
BN Parameters in Large Networks

TNM-Staging Model
Over 78,000 parameters/probabilities
Expert-Friendly Parameter Modeling

~78 000 combinations = 195 000 min
= 3 250 hours

150 parameters an hour ➔ 2.5 min per parameter

[invasion | shape, length(2)]

[van der Gaag2002]
Expert-Friendly Parameter Modeling

[Cypko2015]

- Automatically generated
- Reduced rating time to 10 sec per parameter!
- Web-based

10 sec per answer
~78 000 combinations = 130 000 min
= over 216 hours
Expert-Friendly Parameter Modeling

![Decisive event combinations](image)

**Decisive event combinations**
Are there any influential events that would decide over all the events for `larynx_T_resectability`.

Please, select combinations of events starting with the most influential.

<table>
<thead>
<tr>
<th>Event</th>
<th>No</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>larynx_infiltration_Nvagus</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>larynx_infiltration_Naccessorius</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>larynx_infiltration_Nglossopharyngeus</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>larynx_infiltration_skin</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>larynx_infiltration-pterygopalatine_fossa</td>
<td>no</td>
<td>2</td>
</tr>
</tbody>
</table>

**How likely is it, that larynx_T_resectability is true?**

<table>
<thead>
<tr>
<th>1%</th>
<th>15%</th>
<th>25%</th>
<th>50%</th>
<th>75%</th>
<th>85%</th>
<th>99%</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Probability Graph" /></td>
<td>28%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**How certain are you?**

- Unsure
- Rather unsure
- Rather sure
- Sure

Continue →

78,000 combinations = in under 6 hours!
How to build faster and how to decrease modeler bias?
Collaborative Modeling
Semi-automatic Model Validation

Example of the TNM staging model

- has sufficient complexity (303 variables and 334 dependencies)
- is relatively well described by clinical guidelines
- has an adequate evidence base
- highly impacts the patient-specific treatment decision

1. Quantitative validation
   1.1. Accuracy
   1.2. ROC
   1.3. Confusion Matrix

2. Qualitative validation
   2.1. Patient-Record Validation
   2.2. Submodel Validation

3. Modification
   3.1. Patient Data modification
   3.2. Graph modification
   3.3. CPT Modification
Deployment in the Clinic
Modular Architecture [Gaebel2018]

Diagram of modular architecture with components such as User Interfaces, Central Processing Unit, Data Access & Preprocessing engine, and Model Distribution System.
Standards

Predefined structure and M&V workflows

Established file formats and cross sharing

Established medical knowledge

z.B. SNOMED CT

The global language of healthcare
Oncoflow – Interactive Tumorboard [Meier2014]
Structured, Model-Based Data Input
[Unger2018]
User Interface Designs

Tumor board preparation

During intervention

In the tumor board
Patient-Specific Tumor Board Dashboard

[Integrated Tumor Dashboard]

Head and Neck Oncology
Conclusion and Outlook

• Knowledge-driven modelling approach
• BN-based treatment model for laryngeal cancer
• Expert-friendly modelling approaches
• Partially validated model
• Deployment in the clinic

Outlook:
• Finalization of the model and validation
• Collaborative modelling and update mechanisms
• Deployment in the ENT department
Thank you!
Questions?


