Bringing Data-Driven Process Analysis into Surgical Practice – the Surgical Process Analyzer

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Abstract. The growing number of connected medical devices in the operating room and electronic health records provide valuable data to analyze surgical processes for workflow optimization, context-aware assistance systems and prediction of adverse events. In this area of surgical data science, i.e. surgical process analysis, a key challenge is to combine methods from computer science and statistics with surgical knowledge about processes and data, such as standard operating procedures, surgical guidelines, uncertainty and quality of data. We propose a novel framework that integrates handling of data, knowledge models and data analysis with an intuitive user interface for data visualization, process analytics and knowledge capturing. A key goal of this so called "Surgical Process Analyzer" is to empower surgical domain experts to perform process analysis in their surgical practice. As a result we expect to advance research in surgical data science by addressing real-world use-cases with collaboration of surgeons and data scientists that provides benefit for patients.

Keywords: Surgery, Process Analysis, Knowledge Modeling, Data Science

1 Background

Surgical process modeling is an established field of research and an import part of surgical data science. Modeling and subsequent analysis typically focus on the surgical procedure itself and objective measurements of surgical skills [1] or surgical approaches in different centers [2]. Another relevant field is clinical pathways, in which computer interpretable guidelines lay the foundation for context-aware decision support [3] and data from electronic health records can be used to perform process mining on treatment procedures [4]. However, the widespread adoption of successfully developed methods for process analysis into the daily surgical practice is limited by their usability for non-data-scientists. Our approach aims to overcome this bottleneck.

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2 Surgical Process Analyzer

Aim & Overview.

We propose a surgical process analyzer (SPA), to bring surgical process analysis into surgical practice and thereby advance research in this area of surgical data science into the surgical community. SPA is a framework in which surgeons can easily capture their knowledge about processes in meaningful models, handle their data, analyze their processes and visualize the results. The framework should allow data scientists to develop new methods for surgical process analysis that can quickly be adopted by surgeons analyzing their processes. Figure 1 illustrates an overview of the required components. The following sections describe the requirements for these components and propose a first draft that tackles identified issues.

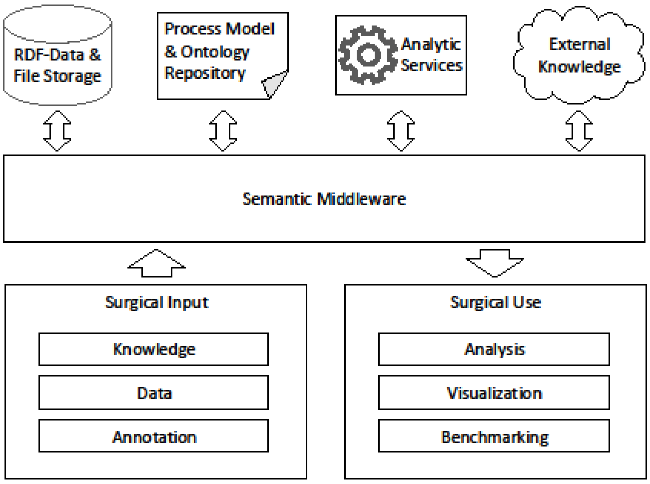

Figure 1: Overview of the components of the Surgical Process Analyzer

Semantic Middleware.

The SPA requires a semantic middleware as its core component. Its purpose is a seamless collection, exchange, access and distribution of knowledge and data between surgeons and data scientists. The integration of novel components, like e.g. analytic modules, can be performed without changing the user interface or data handling. For this component we use the Semantic MediaWiki (SMW) [5]. SMW is a web-based knowledge management system and thus allows a distributed and collaborative work. Moreover, it can easily be extended with new ontologies and analytic services.

Surgical Input.

The surgical input to the SPA comprises knowledge, data and annotations. Knowledge about surgical processes can be obtained from textbooks, publications or surgical practice. By using a SMW structuring of the knowledge can be performed in a stepwise approach from text towards semantic annotations and finally formal expression in an ontology (s.f. process model & ontology repository), fostering collaboration between surgeons and knowledge engineers, Data about processes can be obtained from surgical sensors in the operating room. Also, electronic health records of patients can provide information about surgical events along the treatment process (surgery, diagnostics, hospital stay etc.). Besides providing a database connection by the SPA, we also suggest an interface for common known formats like spreadsheet format. As a result, the SPA allows, among others, uploading structured spreadsheet data and (semi-) automatically mapping it to the data model of the SPA.

RDF-Data & File Storage.
The SPA enables to store structured and unstructured data. Whereas medical devices and electronic health records mainly offer structured data, there is also unstructured data available such as surgical videos and textual reports. To tackle this heterogeneity, we propose to use a RDF-triplestore for the structured data and annotations of the unstructured data to combine both for analyzing purposes. We will follow the LinkedData principles[1] to avoid having an unbounded web.

Process Model & Ontology Repository.
One advantage of the SPA is the incorporation of surgical knowledge into process analysis. To use this knowledge, formal descriptions of processes have to be stored in a machine-interpretable way that also adheres to modeling standards such as the Business Process Model and Notation (BPMN)[2]. Therefore, we integrated a graphical BPMN-editor into SMW [6]. Besides this editor, SMW can be used for collaborative knowledge modeling and provides the possibility to import existing ontologies to describe processes [7] which allows to infer new knowledge.

Analytic Services.
Powerful analytic services are the main benefit of the SPA. Numerous algorithms already exist for different applications within surgery. Hence, we propose to determine existing and important analytic algorithms and provide them as cognitive and reusable services within the SPA [8]. Furthermore, we argue that surgeons should be able to perform the analysis locally to ensure data privacy. For this purpose, we enable the use of locally deployed machine learning tools like e.g. weka to analyse processes and find clinically relevant patterns [9].

External Knowledge.
SPA should be able to integrate external knowledge sources. This does include standards, ontologies etc. Moreover, if surgical process analysis will be adopted by the surgical community, it can be used for external benchmarking by comparing own process analysis results to other surgeons or centers all over the world. However, data security and privacy remains an important issue.

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[1] https://www.w3.org/DesignIssues/LinkedData.html
[2] http://www.omg.org/spec/BPMN/2.0/

Surgical Use.
Surgical data science in general and surgical process analysis in particular need a commitment from data scientists and surgeons alike. Patients benefit if new methods and tools are applied to real world surgical use cases such as workflow optimization or benchmarking.

3 Conclusions

We described our aim of developing a surgical process analyzer. The abovementioned components are separate fields of research, but have to be combined to powerful tools that can be used by surgeons. This will lead to a shift in surgical practice towards data-driven workflow-optimization, benchmarking and prediction of adverse events. Major challenges include the widespread agreement on a shared middleware to exchange components, standardizations of ontologies and process models and building a surgical user base contributing domain knowledge, data and use-cases.

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