SMITH: Smart Medical Information Technology for Healthcare

The SMITH project aims at making better use of the wealth of patient data in order to validate the relevance of novel diagnostic and therapeutic methods in systematic trials, ultimately hoping to directly improve care. One goal is to optimize diagnosis and therapy in intensive care unit (ICU) patients with lung failure. University Hospital RWTH Aachen, RWTH Aachen University, Bayer AG and the Jülich Supercomputing Centre are collaborating in the clinical use case Algorithmic Surveillance of ICU patients (ASIC).

The SMITH project is one of four consortia funded by the German Medical Informatics Initiative (MI-I) including partners from universities, university hospitals, research institutions and IT companies. The benefits for patient care that drives the SMITH project include the availability of actionable, data-driven decision support standardized across healthcare organizations such as the seven German hospitals that are part of the SMITH consortium. The overarching goals are to establish data integration centers (DICs) at each SMITH partner university hospital and to implement use cases, which demonstrate the usefulness of the SMITH approach.

SMITH Use Cases

The methodological use case Phenotype Pipeline (PheP) develops algorithms for annotations and analyses of patient-related phenotypes according to classification rules or structured-data-based statistical models. The word 'phenotype' can be interpreted in a very general sense—in this context, it refers to a set of attributes that can be attached to an individual. Unstructured textual data will be subject to natural language processing (NLP) to permit integration into the phenotyping algorithms. The goal of this use case is creating annotations (aka tags) for a broad spectrum of attributes linked to a specific patients' patterns of care.

The first clinical use case, Algorithmic Surveillance of ICU Patients (ASIC), focuses on ICU patients with acute respiratory distress syndrome (ARDS). A model-based decision-support system will advise medical professionals about mechanical ventilation and is planned to support the daily work within selected university hospital ICUs. The second clinical use case, HELP, develops a hospital-wide electronic medical record-based computerized decision support system to improve outcomes of patients with bloodstream infections. Both ASIC and HELP will use elements of the methodological use case PheP. The clinical benefit of the use cases ASIC and HELP will be demonstrated in a change of care clinical trial based on a step wedge design in hospitals. This article focusses on the ASIC use case.

Clinical Use Case Algorithmic Surveillance of ICU Patients (ASIC)

The demand for intensive care medicine will increase over the next 10—15 years. This can be explained by the epidemiological challenges Germany faces. There is a need for improvement and it is especially urgent in patients suffering from acute respiratory distress syndrome (ARDS), the focus of the ASIC use case. Incidence of ARDS worldwide remains high, with 10.4% of total ICU admissions and 23.4% of all patients requiring mechanical ventilation [2]. The goal of the ASIC use case is to perform a continuous analysis of data obtained from the hospital patient data management system (PDMS) in order to enable model-based 'algorithmic surveillance' of the state of critically ill patients. The ASIC use case, therefore, develops the following two key elements in the form of a model and a decision support system.

Virtual Patient Model

In order to predict individual disease progression of ICU patients, ASIC will utilize pattern recognition technologies as well as established mechanistic systems medicine models, complemented by machine learning and high-performance computing (HPC), both integrated in a hybrid virtual patient (VP) model [3]. This model will enable individual prognoses to support therapy decisions, clinical trials, and training of future clinicians. Training the VP model requires HPC and will take advantage of Markov Chains Monte Carlo (MCMC) methods and deep learning algorithms [4, 5]. HPC computing time estimations for one given VP model is only roughly 2 sec (1 core) but given the uncertainty, 106 runs are required for the MCMC approach, leading to 1 patient in roughly 1,000 core hours. Of course the SMITH project aims to compute at least 1,000 patients' data in many iterations in order to improve modeling. For the foreseen clinical practice with new patients on a daily basis, however, a model reduction is planned by mapping the model onto a deep learning network. Another computationally intensive part of the VP approach is the deep learning network training process. This, in turn, requires HPC for training but also for validation and model selection in order to scan the full parameter space of such a deep learning network.

Diagnostic Expert Advisor

Beside the above described hybrid modeling approach, the ASIC use case will also contribute to the development of an online, rule-based computerized decision-support system (CDSS). This system will extensively use a wide variety of DIC services and the Phenotype Rules-Engine that applies phenotyping rules developed in the PheP use case. The goal of CDSS in clinical practice is to accelerate correct and sound diagnosis and increase guideline compliance regarding ventilation. The rules that drive the CDSS design are realized by explicit decision trees, complex models, mechanistic or machine learning-based, or combinations of both. The main component of this CDSS system is the Diagnostic Expert Advisor (DEA) and all elements of the ASIC system will be accessible via an ASIC app. This app will provide the interface between the DIC, the surveillance algorithms outlined above and the medical professionals at the bedside. It enables the functionality of automatically informing physicians if a priori specified limits are exceeded. This alert function will be enhanced by the latest action-based algorithms, preventing medical professionals from moot alerts (and, thus, alert fatigue).

References

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