AI Support for Medical Decision Making

PhD project proposal by Marina Axelson-Fisk

The specific aim of this PhD project is to develop, implement and evaluate a core model for longitudinal decision support in the diagnosis of infectious diseases, using Markov Decision Processes (MDPs) and reinforcement learning (RL). Key objectives of the resulting system are accuracy, robustness, and transparency. This project is part of a larger project involving researchers at Software Engineering, Chalmers, and physicians at Sahlgrenska University. In order to optimize its usability and explore new research findings, the model will be trained and tested intermediately by practitioners at the hospital during the development.

Medical treatment decisions are often executed sequentially and in an uncertain and varying environment. A decision support system suitable to the diagnosis and treatment of infectious diseases need to handle vast amounts of diverse data and be able to update diagnosis and treatment plans sequentially in real-time. Particularly for severe infections such as sepsis, early diagnosis is crucial, and the subsequent treatment plan is critical and highly individual (Komorowski, *Nature Med* 2018). Moreover, in order to enable well-informed decisions, the basis for a suggested diagnosis and treatment plan needs to be highly transparent and efficiently visualized to the attending physician. Therefore, the core of the decision support system will use Markov decision processes (MDPs) in combination with reinforcement learning. MDPs are powerful tools for modeling dynamic systems under uncertainty and are superior to most decision models due to their ability to identify optimal decision policies in sequential data and over a wide variety of objectives. Another strength is their transparency and interpretability, such that full information about the competing policies to be provided during the decision process, including their relative strengths and the influence of specific model features on the range of possible diagnoses. This provides the decision maker with robust and powerful support for making ethically sound decisions.

This project proposal is part of a larger, multi-disciplinary, and collaborative effort called HiACE (High-fidelity Intelligent Automated Clinical Evaluation), including the research groups of Robert Feldt (Software Engineering, CSE) and Lars-Magnus Andersson (Sahlgrenska University, Östra). The goal is a decision support system that can integrate data in various formats and from a multitude of sources, and choose between multiple diagnoses in a situation where decisions must be made sequentially in a variable environment.

The project can be divided into two major goals:

1. Model development: developing an MDP suitable as the core of a decision support system for diagnosis of infectious diseases. This involves developing the model architecture, including defining specific state models for various types of data, as well as addressing the issues regarding non-stationarity, and suitable rewards and discount structures mentioned above.
2. Model implementation, training, and evaluation: besides the actual programming, this part includes the needed efforts for complexity reduction, such as feature selection, action elimination and state aggregation, as well as the testing and evaluation of the model accuracy and efficiency.

The PhD student will work on the theoretical aspects of the model, and extending the MDP theory to a semi-POMDP that suits the medical decision-making situation. She/he will also work on extending techniques for adversarial generation of test case to ensure robust behavior of MDP decision support systems. The project will be in close collaboration with the entire HiACE team.