Digital Health and Connected Healthcare
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Master Project Summer 2021

In cooperation with the surgery department
of the Virchow clinic Berlin at Charité.

HPI Hasso Plattner Institut
IT Systems Engineering | Universität Potsdam

Predictive Maintenance for Patients

Detecting Critical Conditions and Complications Before They Occur Using Machine Learning

Overcoming and accurately dealing with unforeseen events makes up for a substantial part in both our personal as well as our professional lives. This is particularly true in the field of health care, where complications in the course of medical procedures may worsen patients' morbidity or even putting his or her life at risk. Thus, it is important to use **preventive** or **predictive maintenance** in these circumstances to foresee potential complications and enable better patient care. Unfortunately, the current clinical practice is still mostly corrective maintenance, which only addresses problems after they have already occurred, which is clearly a problem for patients.

As a prevention measure, **machine learning** models can be trained on existing patient data to support doctors and medical staff in hospitals with predictions. The challenge often lies in the **data preprocessing** and **data engineering**, since data exists in many different formats and is taken from a multitude of medical systems and devices. Body-worn sensors are prone to noise by movement, which has to be filtered out. In addition, a lot of patient information is manually entered by nurses, who are traditionally overworked and may not have the capacity to double check all inputs. Thus, a lot of data cannot be trusted without proper cleaning and medical expertise.

When a complete and cleaned dataset is reached, the choice, development and testing of suitable machine learning methods is incredibly important. Different models may perform very unevenly for different prediction tasks.

In this Master project we want to address the whole pipeline from data preprocessing and data engineering to machine learning. We plan on investigating two different but related topics:

ICU Alarm Management

In intensive care units (ICUs), medical monitors trigger an alarm when physiological parameters exceed or fall below certain thresholds. For example, when the patient's heart rate goes below 60 bpm, an alarm will be triggered so medical staff is informed and can take action. The problem with this approach is, that there are so many alarms at an ICU, that the staff becomes fatigued and desensitized, hence not responding properly to every alarm.

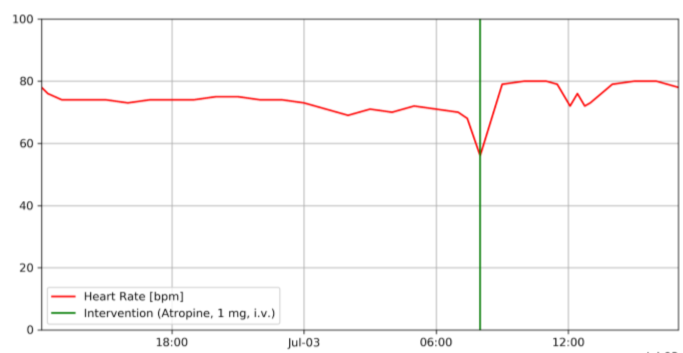

Figure 1: As soon as the heart rate falls below 60 bpm, an alarm is triggered, and countermeasures are taken.

This project aims to **predict alarms from trends** in the physiological parameters. Thereby, alarms – which are supposed to indicate acutely critical conditions – can be replaced by scheduled tasks. Instead of triggering an alarm when the heart rate is already below 60 bpm, we can detect that the heart rate will probably fall below 60 bpm during the next hour and notify the medical staff to look after the patient when they have time. Thus, minimizing stress in staff and critical conditions in patients.

To this end, we use **large clinical databases** such as MIMIC-III and HiRID. These databases contain all events, measurements, and patient records gathered in an ICU in a certain timeframe. This allows to perform **time-series forecasting** on patient data using machine learning models such as Recurrent Neural Networks (RNNs) and Hidden Markov Models (HMMs).

Federated Learning for Predicting Complications after Surgery

After surgery, patients are at risk of developing complications. Detecting these complications as soon as possible is crucial in order to avoid adverse outcomes and even death of the patient.

Machine learning generally scales with the amount of available data. However, data privacy regulations such as the **GDPR** often prevent freely sharing patient information across hospitals. **Federated learning** (see Fig. 2) is an approach aiming to enable multi-centre machine learning by sharing the model instead of the actual data.

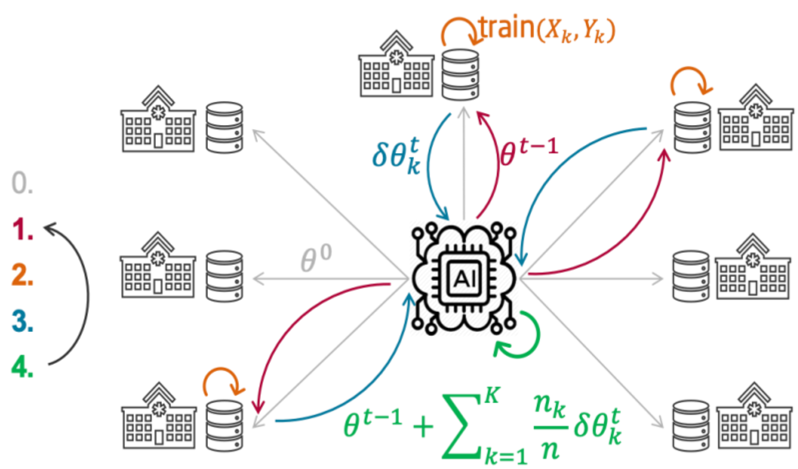

Figure 2: Overview of a federated learning system. A model is jointly trained by exchanging model parameters found through local training, instead of the private data itself.

The Charité – Universitätsmedizin Berlin consists of four distinct campuses in addition to multiple teaching hospitals and collaborative research centres. Many surgeries are performed at multiple locations, meaning that patient data is scattered across the different sites. The goal of this project is to develop federated learning methods for this distributed data to improve predictive models for complications after colorectal surgery. This includes the selection of an appropriate prediction model for the given use case and the investigation of potential privacy issues. You will receive access to **multimodal, real-world medical data** from campuses Mitte, Virchow and Benjamin Franklin and investigate the benefits of using federated learning instead of training multiple distinct models.

Requirements and Expectations

This is an interdisciplinary project with aspects of computer science and medicine. Hence, a broad and diverse field of expertise is required.

Regarding computer science, this project will cover:

- Processing large amounts of medical data,
    - Data pre-processing
    - Data engineering
- Time-series data
- Machine learning
- Federated learning

Regarding medicine, this project will cover:

- Human physiology,
- Pharmacology
- Visceral surgery

Don't worry, you do not need to have prior knowledge in all of these fields. Since HPI has different master programs, we expect the medical knowledge mainly coming from digital health students and computer science knowledge mainly (but not exclusively) coming from all other master students.

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