DIGIPREDICT

EPFL

Towards designing a Digital Twin for ICU patients:

Data & Visual Analytics

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Introduction

Digital Twins in healthcare. A Digital Twin is a virtual instance of a physical system (twin) that is continually updated with the latter's performance, maintenance, and health status data throughout the physical system's life cycle [Madni, 2019]. In this technology, the data should flow from physical object (the patient) to the digital twin. The ultimate goal is to enhance decision making process of clinicians by providing new knowledge to them. ***Data analytic tasks are the core component of a successful digital twin, and the output could be better interpreted by clinicians through visual analytic tools*** (Fig1).

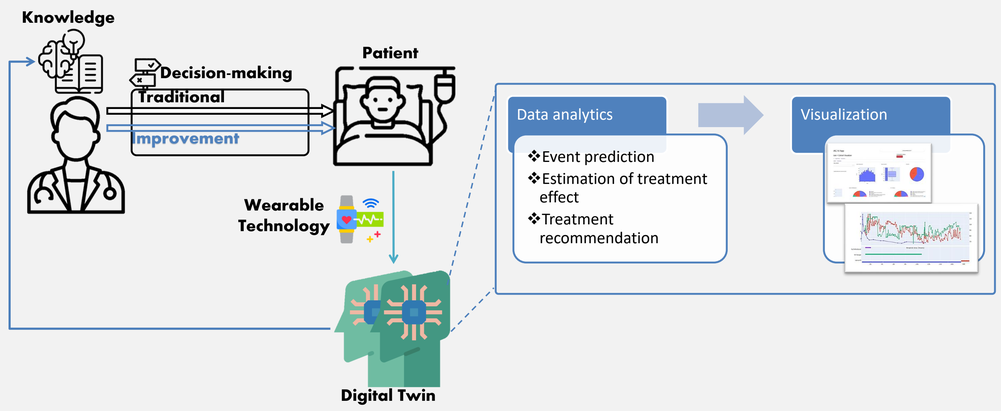


Figure 1. A Digital Twin in the healthcare

DigiPredict Project. By closely monitoring the dynamic of disease-specific biomarker, it is possible to improve the accuracy of machine learning methods to detect specific clinical events such as myocardial infarction, sepsis shock, mortality, etc. This will make treatments more effective, personalized and will reduce costs by the possibility to early discharge patients.

Objective. In this work, we have designed an initial version of the ***visual interface to explore an existing ICU database*** because the DigiPredict sensors are not yet validated through standard clinical trials. This interface ***can be further developed by incorporating more data analytic algorithms***.

Materials & Methods

Dataset. We explored various existing ICU databases that are publicly available (Table 1). We selected Medical Information Mart for Intensive Care (MIMIC) IV [1], which is a real-world clinical database comprising health data relating to over 40,000 patients admitted to ICU at the Beth Israel Deaconess Medical Center.

Table 1. publicly available ICU databases

Database	location	Period	Published	# of patients	Vital signs grid
MIMIC-III	BIDMC	2001-2012	2016	>40,000	1 hour(*)
MIMIC-IV	BIDMC	2008-2019	2021	>40,000	1 hour
eICU	USA (multicenter)	2014-2015	2019	>200,000	5 min
HiRID	Bern hospital	2008-2016	2021	>36,000	2 min
AmsterdamUMC db	NL	2003-2016	2021	~4,000	1 min
BIDMC: Beth Israel Deaconess Medical Center *waveforms available separately (grid: seconds)					

Software. We utilized Dash apps which give a point-&-click interface to models written in Python. Using this tool we can put complex Python analytics in the hands of clinical decision-makers and operators. In the back-end we used structured query language (SQL) to access the database.

Results

The visualization interface consists of two modules.

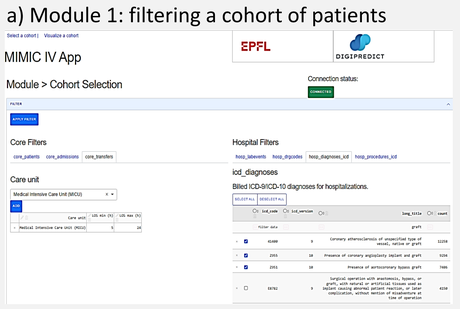
Module 1: Cohort Selection

In this module, the user can select a subset of hospital admissions by defining various filters for demographics, care unit stays, and hospital information such as lab measurements and ICD codes (see Fig2.a). As an example, we have filtered a cohort of 3478 patients with *Coronary artery bypass graft (CABG) using ICD procedures codes 021209W and 36.1*.

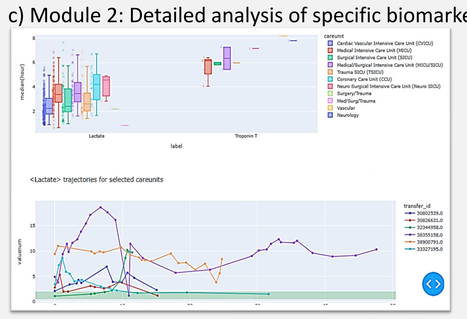
Module 2: Cohort Visualization

The first step is to load a desired cohort which has been selected in the previous module. Then, an initial information (age and gender distribution, length of stays in different care units and most common ICD codes) is shown through interactive visualizations (Fig2.b). In addition, there is a possibility to analyze trajectories of biomarkers (Lactate, cTn, …) that are planned to be measured by wearable sensors in DigiPredict (Fig2.c). Finally, the user can load a specific hospital admission and visualize trajectories (vital signs and lab measurements, ICU chart events, procedures, medications and many more) (Fig2.d)

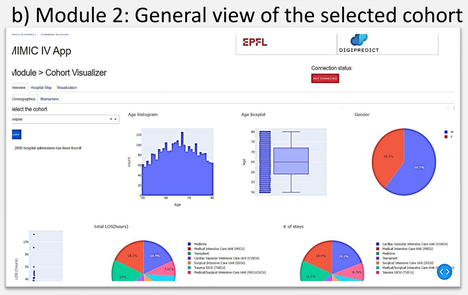
a) Module 1: filtering a cohort of patients



c) Module 2: Detailed analysis of specific biomarkers



b) Module 2: General view of the selected cohort



d) Module 2: Trajectories for a specific patient

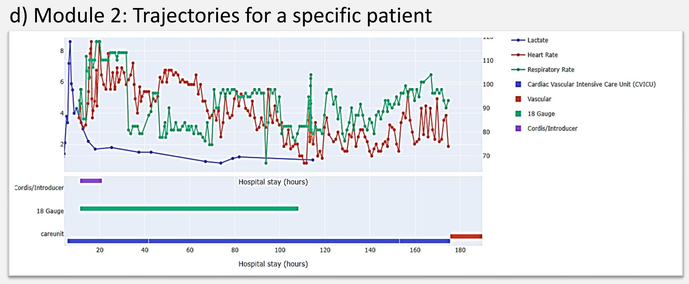


Figure 2. A Digital Twin in the healthcare

Next Steps

- ✓ Developing a prediction algorithm for detecting myocardial infarction of patient Coronary artery bypass graft (CABG) surgery
- ✓ Developing a treatment response estimation tool for CABG patients
- ✓ Incorporating developed data analytics in the visual interface

Acknowledgments

[1] Madni, Azad M., Carla C. Madni, and Scott D. Lucero. "Leveraging Digital Twin Technology in Model-Based Systems Engineering." *Systems* 7, no. 1 (March 2019): 7. https://doi.org/10.3390/systems7010007.

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