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Complex data-driven predictive modeling in personalized clinical decision support for Acute Coronary Syndrome episodes

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Abstract

The objective of this paper is to demonstrate the development of complex model of clinical episode, based on data-driven approach, for decision support in treatment of ACS (Acute Coronary Syndrome). The idea is aimed at improving predictive capability of a data-driven model by combining different models within a composite data-driven model. It can be implemented either hierarchical or alternative combination of models. Three examples of data-driven models are described: simple classifier, outcome prediction based on reanimation time and states-based prediction model, to be used as part of complex model of episodes. To implement the proposed approach, a generalized architecture of data-driven clinical decision support systems was developed. The solution is developed as a part of complex clinical decision support system for cardiac diseases for Federal Almazov North-West Medical Research Centre in Saint Petersburg, Russia.

*Keywords:*data-driven modeling, decision support system, clinical DSS, personalized medicine, p4 medicine

1 Introduction

Acute coronary syndrome is one of the common form of heart diseases which causes immediate death, worldwide. Following appropriate medical treatment strategy, as soon as the patient admits to the hospital, is essential for best outcomes. However, the unfavorable circumstances while making decision such as insufficient objective data and lack of time are common in contemporary medical practices. Medical treatment outcomes are characterized by a number of factors, ranging from patients' survival rate to duration of treatment and cost of used methods, which reflect economic aspects of the problem.

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The strategy of managing ACS patients is defined in detail by ESC Guidelines [1], [2]. Nevertheless, each individual cases have their own features which in turn require specific decision making process and are not regulated by the recommendations based on a wide interpretation and extrapolation of scientific data and personal clinical experience of the doctor. Modeling ACS medical emergency patients can be extended by including cases which demand intensive care, because this stage obliges resolution of main issues such as diagnosis, determining treatment strategy, high risk of complications and significant economic costs. Infrequent outcomes are analyzed based on the details of treatment considering the stay in various departments and in-hospital logistics. However, analysis of the data accumulated in the hospital information systems opens up new possibilities of seeing these aspects of acute cardiac care from different angle [3]. Therefore, decision making support in the treatment of patients with ACS is a very important issue which requires effective models. One of the popular models is Cox model or proportional hazards model [4]. This model allows us to predict a risk of certain events and the influence covariates have on this risk. Cox model is based on the assumption that a risk function can be described as the basic hazard rate function and the function of covariates which affects multiplicatively the resulting risk. Typical medical covariates are treatment assignment and patient characteristics such as age, gender, and other diseases at the start of treatment.

Phase-type (Ph) distributions [5] area is a popular way to model how long a patient stay (LOS, Length of stay) in a hospital [6]. Ph-distributions is the distribution of time in a finite-state Markov chain with only one absorbing state and where process starts at a random transient state. In this model time is represented as a sequence of phases and terminates when the process reaches an absorbing state. Various machine-learning and data-mining models provide powerful tools for clinical predictions [7][8]. They are widely used for medical diagnosis [9], LOS prediction [10], [11], event prediction [12], [13], prediction of need for life-saving interventions [14] and many others.

There are several works which describe ways how different approaches can be joined into one to get better results. [15] describes an approach of Conditional phase-type distributions for task of LOS modeling, which combines the use of Ph-distributions and Bayesian belief networks. [12] proposes an integrated approach for stroke prediction including a systematic method for imputing the missing entries, selecting relevant feature subsets, and the Margin-based Censored Regression.

Single models show good results in a single variable prediction but ineffective when we do not have full information at the moment of prediction. Another difficulty is the fact that a patient may face many clinical events (more details provided in Section 2.5), and a model should take parameters of these events into account. Simple extensions of the set of features of models may be ineffective since only few of many possible events can happen with a single patient, and passing all of them as models' parameters may add much noise.

In our work we propose the idea of a complex model of clinical episode, based on data-driven approach for decision making support in ACS treatment. Our model will use some models' output as inputs for possible early prediction, when full data for prediction is unavailable; it will take into account incoming data about various medical events or procedures which are difficult to predict at the time of patient's admission to the hospital.

2 Model of a clinical episode

2.1 Problem statements

Federal Almazov North-West Medical Research Center has an opportunity to access depersonalized cards of the patients who had acute coronary syndrome (ACS). These cards were used in our analysis. Electronic Medical Records (EMR) reflect clinical records of a patient and contain information about all cases of patient's treatment or complaints to the medical institution. EMR of a patient is a collection of clinical incident (ambulatory, stationary) and various tickets (or cards) for medical assistance. Our