Allocation Policies in Emergency Departments using Consultation Time Predictions

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Mots-clés : *Emergency Departments, Patient Allocation, Queuing Networks, Consultation Time, Probability Density Functions Prediction*

1 Introduction

Emergency department (ED) overcrowding has been a prevalent issue for several decades in hospitals around the world. Particularly, ED crowding generally reduces the quality of care, increases the waiting time of patients or induces dissatisfaction for the physicians. The prioritization policy between patients influences this process. Therefore, developing patient allocation models can improve the operation of EDs.

A common practice in EDs around the world is to use a *triage* system to allocate resources and provide guidelines for classifying patients into priority groups (triage levels) based on their acuity, urgency, and resource needs. Hence current prioritization models may depend solely on the severity of a patient but not on the complexity of the service. However, it has been shown that ED operations can be improved by incorporating both the complexity and urgency information of the patients into the scheduling decisions [1].

In this work, we propose a patient allocation model incorporating consultation time predictions. The ED is modeled as a queuing system [2]. We then simulate the operations of the ED using a large set of data from a University Hospital in Montreal. This data is also used to train a model for predicting consultation time probability densities. We propose several allocation policies that use the consultation time predictions and aim to reduce a given cost. These allocation policies are compared to benchmark policies that are found in the literature on similar problems.

2 Solution Approach

2.1 Consultation Time Prediction

The historical data used consists on a large set of entries (more than 300,000) collected over ten years in a University Hospital in Montreal. This data is described by several patient's characteristics such as the date and time of arrival, the symptoms, the assistance needed , the vital signs, etc. We also have information on the triage level and consultation time.

Because the consultation time might depend on several factors that are external to our data, it is more appropriate to predict a probability density rather than a deterministic duration. We propose several parametric densities derived from exponential distributions and evaluate how they fit some empirical distributions extracted from our data set. We then use a neural network trained on a large part of the data to predict the parameters of the probability density functions of consultation times.

2.2 Patient Allocation Model

When patients arrive to the ED, a first diagnosis is carried out, which makes it possible to identify their characteristics and to assign them a triage level. Patients go to the waiting room where they remain until they are assigned to a physician. After their first consultation, patients may leave the ED, undergo diagnostic tests or receive treatment to be later discharged or hospitalized.

We assume that patients arrive in the waiting room according to a non-homogeneous Poisson process. Knowing the characteristics of patients, the prediction model described above predicts the probability densities of their consultation time. We consider a constant number of physicians available during the simulation. When a physician arrives or finishes its current consultation and becomes free she chooses a patient from the waiting room according to an allocation policy and keeps her in consultation whose duration is determined by the historical data.

2.3 Allocation Policies

An admission policy allows to choose which patient will be assigned to a free physician knowing the characteristics of the system (waiting room occupation, predicted consultation time densities, consultations in progress, etc.). We propose a parametric penalty function to measure at the end of a simulation the quality of the allocation policy taking into account several factors like the patients' danger threshold or their waiting time.

The effectiveness of benchmark policies presented in the literature on similar problems are compared. We then propose new tailored policies which can be classified into two families. The first (*SWEXI*) seeks to optimize the impact of the decision on estimations of the cost while the idea of the second (*MYRO*) results in the myopic optimization of regrets. Table 1 shows an overview of the obtained results for both families of policies under different traffic intensity in the system: rates smaller than 1 indicate better performances than usual triage prioritization policies.

Traffic intensity	**0.8**	**1.0**	**1.2**
SWEXI	0.96	0.72	0.86
MYRO	0.93	0.64	0.77

TAB. 1: Rate of penalty compared to a triage prioritization policy

3 Conclusions and Future Work

We modeled EDs as queuing systems whose operations are simulated based on real data. These data also allowed us to propose a model for the prediction of consultation time density functions. A penalty function has been proposed to measure the quality of ED operation according to several factors. We were thus able to compare the effectiveness of existing allocation policies as well as to propose new tailored policies.

Future research perspectives include more in-depth work on the consultation time prediction model, more realistic models and the development of more advanced allocation policies that incorporate future states of the waiting room.

References

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