



Prediction model of outpatient flow based on behaviour data of outpatients in a Chinese tertiary hospital



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ABSTRACT

Objective: Outpatients at Chinese tertiary hospitals are always over-crowded due to the “walk in” mode and all of the services provided within the hospital, which include patient interviews, lab workups, imaging examinations and prescription fill. The aim of this study was to build a model to predict sequential patterns of the services that the patients sought to use and then provide advice for what services they can choose and in which order to avoid long waiting times.

Method: Data collected from outpatient information systems were used to construct a data warehouse. Using the Hadoop distributed platform, outpatient data were processed and analysed using SparkR. The algorithms used included exploratory data, correlation analysis, and machine learning algorithms to analyse the patient flow data.

Results: Approximately 2 hundred thousand qualified records were used for the training set, and 89 thousand records were used for the test set. A prediction model for patient flow was built to predict a patient's selection from the patients who utilized more than one service in a single outpatient visit. This model can predict the patient's behaviour of filling prescriptions before going to other services (lab tests or imaging examination), with accuracy rates of 80.94 and 73%, respectively. Diagnosis classification, insurance type, gender and the other three attributes were considered key factors affecting the patient's selection.

Conclusions: This model calculates the selection likelihood of each patient after seeing a doctor and then estimates the number of patients waiting at the in-hospital pharmacy, laboratory and radiology services within a time interval (e.g., half an hour). In addition, it can be used as a guide for outpatient services in Chinese tertiary hospitals after further optimization.

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1. Introduction

Different from the “reservation” mode in America and Europe, “walk in” mode is commonly used for outpatient services in China. At the same time, due to the current lack of experienced clinicians, advanced modalities and multiple drug types available in community hospitals, patients prefer going directly to tertiary hospitals for outpatient services. Therefore, outpatients at tertiary hospitals are always overcrowded, especially in big cities in China.

For example, in Beijing, the capital of China, 11 hospitals had outpatient visits totalling more than 1.8 million, and the largest among them had over 4 million outpatient visits in 2014.

The usual process for outpatients in China consists of four steps (Fig. 1). Step 1 is outpatient registration, Step 2 is the doctor interview, Step 3 is payment, and Step 4 is seeking different services according to the doctor's request. These services typically include filling a prescription at the in-hospital pharmacy, performing lab tests and imaging examination.

The tasks in first three steps are very clear, and regardless of how long the waiting time is, a patient must follow those three steps without choice. At the same time, many approaches to reduce the waiting time or expedite the waiting queue have been explored for services in these three steps by utilizing Information Technology [1–5]. These approaches include self-service or online registration, online payment and a consulting room calling system.

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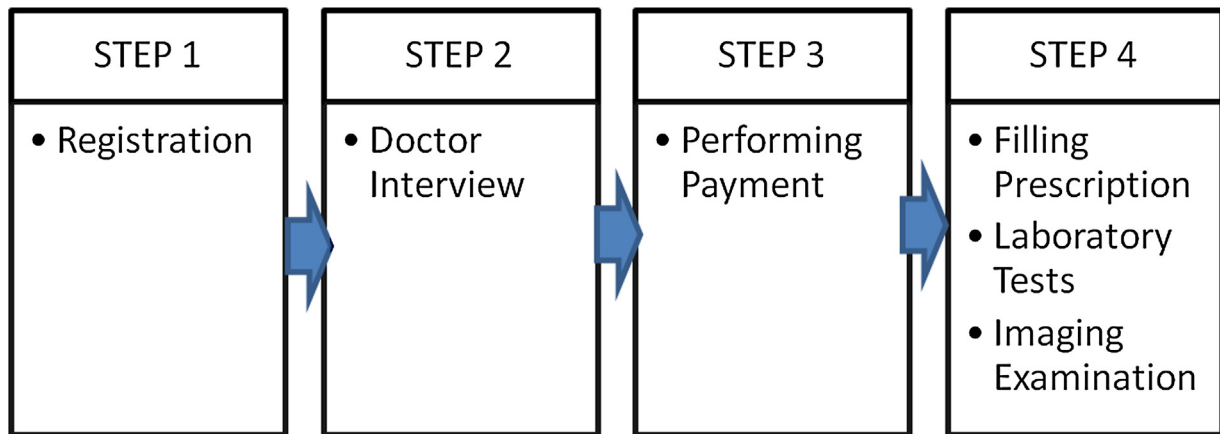


Fig. 1. The usual process of outpatients in China.

Step 1 is outpatient registration, Step 2 is the doctor interview, Step 3 is payment, and Step 4 is seeking different services according to the doctor's request. The medical services in Step 4 may include filling prescription at the in-hospital pharmacy, performing lab tests or imaging examination.

However, in Step 4, patients who need multiple services may face several choices, such as filling a prescription before undergoing an imaging examination or undergoing an imaging examination before filling a prescription. The choice that the patients make will affect the queue length and waiting time at the services in Step 4. Currently, there is no way to display the queue length for those services to a patient who may need multiple services. The patients might run back and forth among different windows to find the service for which fewer people are waiting. This can significantly increase the disorganized movement of patients in the outpatient area. In addition, the patients' anxiety and the possibility of conflict between doctors and patients increase accordingly [6]. As Machine Learning algorithms are increasingly widely used to analyse medical big data [7–11], it has become possible to predict patients' behaviour based on their previous behaviour data. Studying these data may help alleviate the disordered state of outpatient services in China.

The aim of this study was to establish a prediction model to estimate the patients' queuing selection for services after his/her payment action. Based on these estimated data, this study attempts to calculate the possible number of patients waiting for each service in a specific period of time and then provide explicit queue information for patients who need to choose a service window to alleviate their disordered movements and reduce their anxiety.

2. Methods

Originally, in Chinese hospitals, patients' behaviour was estimated based on experience of hospital staffs. At present, someone may use patients' behavioural data stored in Hospital Information System to perform basic statistic, but the results simply showed patients' distribution and cannot reveal root factors that affect the patients' behaviour. In this study, we plan to use Big Data techniques to investigate deeper relationship among multiple factors that may affect patient behaviours based on the patients' behavioural data with large volume and well structured.

2.1. Basic idea

In each time period, the patients in Step 4 can be divided into three types: 1) need only one medical service, as doctors suggest; 2) need more than one medical service; and 3) do not need any further medical services. Patients of the first type do not need to choose which service should be performed first because they are only seeking one service from the hospital. Only patients of the

second type need to choose which service should be performed first. The study aims to estimate the possible first selections of the second type of patients at each service department. By counting the estimated number of the second type of patients who will use that service first plus the certain number of the first type of patients who need that service, we can get the probability of the waiting list at this service in this period of time.

For example, in the last 30 min, the number of the outpatients who pay only for filling prescription is N_p , the number of those who pay only for lab tests is N_l , and the number of those who pay only for imaging examination is N_i . Then, the prediction model can be calculated for this time period. The estimated number of outpatients with multiple service needs who will fill a prescription first is M_p . The estimated number of outpatients who will undergo lab tests first is M_l . The estimated number of outpatients who will perform imaging examination first is M_i . Therefore, the total patient number possibly waiting for filling a prescription, lab tests or imaging examination can be calculated using formulas 1, 2 and 3.

$$S_p = N_p + M_p \quad (1)$$

$$S_l = N_l + M_l \quad (2)$$

$$S_i = N_i + M_i \quad (3)$$

Based on previous data from our hospital, the first type of patients accounted for approximately 60%, and the proportion of patients in the second type accounted for 26.3% (Table 1). The main work in this study was to create a patient behaviour model for this 26.3% of patients.

Table 1

Proportion of outpatient patients with different services in Step 4 in one general hospital in 2014 and 2015.

	One service	Two or more services	No service
2014	60.2%	26.3%	13.5%
2015	60.4%	26.3%	13.3%

Notes: **one service** column – outpatients who only need fill prescriptions, only perform lab tests or only perform image scans as doctor's request. **Two or more services** column– outpatients need to take multiple services in one visit to outpatient as doctor's request. **No service** column– outpatients who do not take any service in this visit after interviewing with doctor.

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