Application of Big Data to Study Patient Flow in Intelligent Hospitals: A Review

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Background and Purpose

Instead of using traditional data, patient flow studies obtain and analyze big data. With the rapid development of indoor positioning systems, big data such as WIFI fingerprint and event logs (Mans et al., 2008) has been increasingly used inside buildings. As for hospital research, fortunately, intelligent hospital construction has brought electronic health records derived from the healthcare information systems (HIS) (Linder et al., 2007). The record with time and position tags of every single medical sequence, could be linked to each patient (Trebble et al., 2010). In this way, researchers could explore either individual's movement tracks and clinical sequences (Jun et al., 1999), or group's activity patterns (DeFlitch et al., 2015) and clinical paths (Rismanchian & Lee, 2017). This paper focuses on patient flow studies combining big data and multiple analysis tools such as from-to chart, process mining, process mapping and simulation, in order to provide evidences for medical planning.

Fig. 1. Questionnaire (Resource:https://www.surveymonkey.com/curiosity/best-wordpress-survey-plugins-in-2020-12-options-compared)

Fig. 2. Observation (Resource: https://www.marketing91.com/observation-method)

Fig. 3. Big data (Resource:https://futurenow.com.ua/en/why-is-big-data-important)

Theoretical Basis

Patient-Centeredness

The theoretical basis of patient flow analysis is a nursing concept named "patient-centeredness". The concept emphasizes that the fundamental task of medical service and hospital design is to focus on medical effects and patient experiences on the basis of medical laws and medical process. In general, hospital design has witnessed a shift from focusing only on workflow to taking patient flow into account.

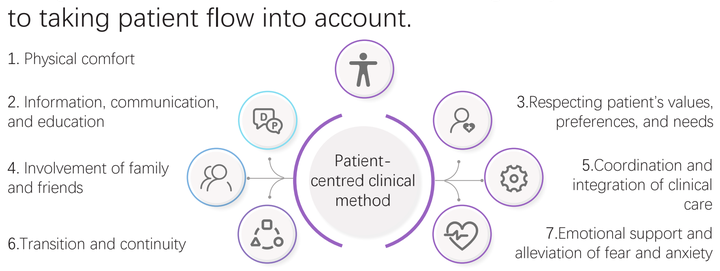

Fig. 4. Patient-centred clinical method (Gerteis, 1993)

LEAN Thinking

The methodological basis of patient flow analysis is LEAN Thinking, a management method originally proposed by the automobile production enterprise—Toyota. The core of LEAN Thinking is to optimize processes, reduce costs and wastes, as well as improve the service quality (Ohno, 1988). In hospitals, patients' long-distance transferring and long-time waiting is defined as non-value activities according to LEAN Thinking (Westwood et al., 2007). The approach to eliminate such activities is to match the space size and allocation with the medical process. As a link between space and process, patient flow analysis provides valid tools for scientifically defining non-value activities in architectural space, and brings opportunities for hospital design to improve towards refinement.

New Access to Big Data Brought by Intelligent Hospital

The development of intelligent hospital has brought new big data access including event log, surveillance video and WIFI fingerprint, etc. Similar approaches have been widely applied to the fields concerning about two-dimensional positioning, such as geography and urban planning(Liu et al., 2014; Long & Thill, 2015). It should be noted that we can use a unique kind of big data, namely the electronic health record stored in HIS, to understand patient flow. From the patients' perspective, HIS records the event information, including content, location and time, in the entire medical process simultaneously as it happens, and forms a systematic database, in which the data is objective and reliable.

	ACCESS	ADVANTAGE
BIG DATA	Healthcare information system	1. The amount of data is large and grows rapidly. 2. Data with time and location tags can be linked to individual patient. 3. It is easy to obtain and sort a large amount of data in a short time. 4. Data is easy to be visualized. 5. Manpower, property and time can be saved.
	Surveillance video	
	Wireless indoor positioning	

Table. 1. Characteristics of big data access approaches (Ai et al., 2016; Karvonen et al., 2017; Rismanchian & Lee, 2017)

Analysis Methods

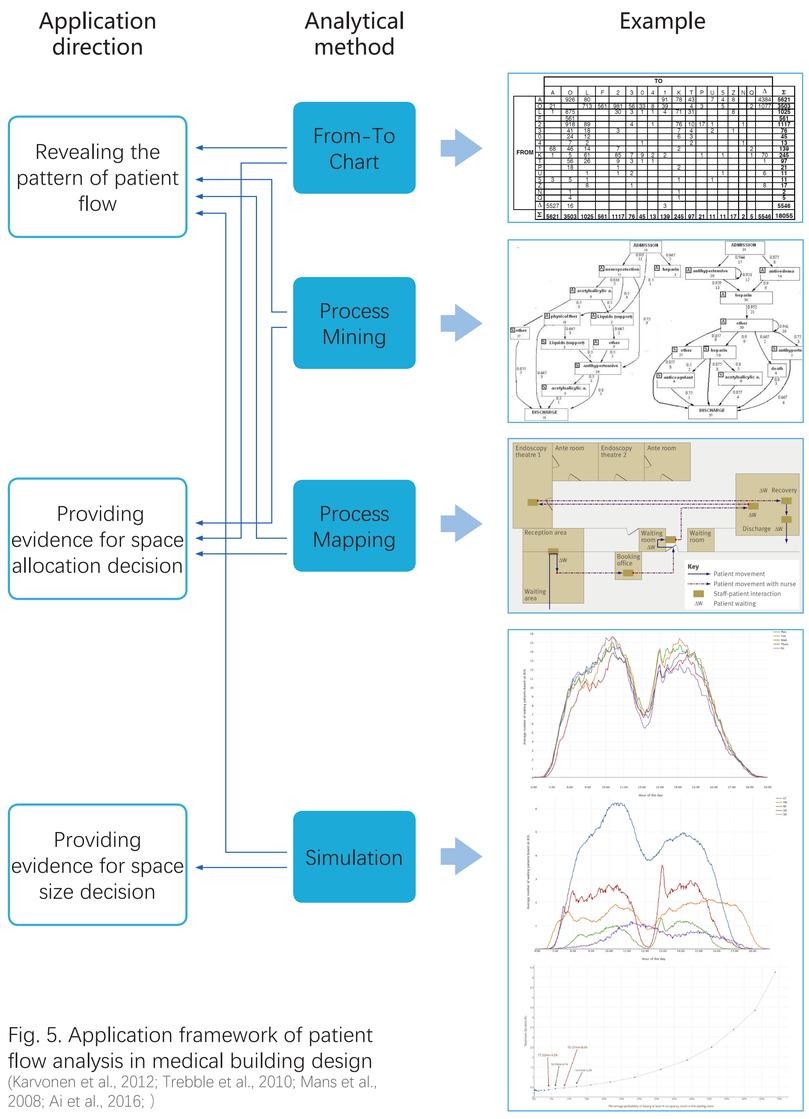

Fig. 5. Application framework of patient flow analysis in medical building design (Karvonen et al., 2012; Trebble et al., 2010; Mans et al., 2008; Ai et al., 2016;)

From-To Chart

From-to chart is a matrix counting travel distance and number of transfers between points. The horizontal and vertical coordinates of the matrix are the origins, destinations as well as the points along the way. After defining the functional attributes of the points, we can classify the patients' activity paths, and count patients' travel data including both flow and direction in the matrix. In this way, by applying descriptive statistics, we can quickly identify the paths, which are long, or used in a high frequency, or carrying a large amount of traffic or multiple transfers. From-to chart, which plays an important role in medical planning, could be applied to the design and evaluation of hospital layouts.

Process Mining

Process mining is a data mining method, essentially. The aim of process mining is to extract information about medical activities and their casual relations, in order to represent the real process and monitor the consistency of real and ideal process. As it is the basis of process optimization, process mining could help designers to understand medical process and department relationship, identify process bottlenecks, as well as explore optimal layout. This method could be applied to making decisions and conducting evaluations of architectural design.

Process Mapping

Process mapping presents all the steps experienced by patients in the medical process by a visual approach (Trebble et al., 2010). It could help researchers to understand the patient flow among various departments, define the roles of staff and patients and reveal the bottlenecks in medical process (DeFlitch et al., 2015), in order to evaluate hospital layout. By marking the facilitators and barriers of patients' activities on the map, problems in the layout can be directly discovered. The map provides a basis for eliminating or merging non-valuable steps (Peterson & Kane, 1997; NHS Modernisation Agency, 2005), and helps to propose improvement approaches (Kollberg et al., 2007; Bevan & Lendon, 2006).

Simulation

The simulation method here refers to a technology that predicts space size based on patient flow and other operational data. Previous literature has proposed three models that have been commonly used. Firstly, linear regression model is often used to predict the size of waiting space in a hospital(Ai et al., 2016). Secondly, based on the hospital's operational plan and architects' experience, process model predicts building size by establishing relationship model between the number of consulting rooms (or the size of waiting space) and other 3 parameters including patient number, staff number and turnaround time of consulting rooms (or waiting space) (Williams et al., 2012a) Thirdly, discrete-event simulation is an operational research technique that allows the end user to assess the efficiency of existing healthcare delivery systems, to ask 'what if? 'questions, and to design new systems (Jun et al., 1999).

Application Framework

Revealing the pattern of patient flow

Patient flow could not only reflect the operational modes of medical process, but also be the evidence for designing layouts of medical buildings. Objectively describing the patient flow could help designers to make scientific decisions in early stages of the projects, as well as to conduct proper evaluation after the design is completed. Many researchers in the fields of medical management and data science have made explorations. This part of fundamental research, on one hand, heuristically reveals the real medical process experienced by patients (Mans et al., 2008, 2009), and on the other hand, interpretively discusses the potential factors related to patient flow (Soriano-Meier et al., 2011; Vos et al., 2007).

Providing evidence for space size decision

One of the application directions of patient flow analysis in hospital design is to predict the size of building space in the architectural planning stage. In this sort of studies, we usually use patient flow to predict the number of consulting rooms and examining rooms (Williams et al., 2012b), or the size of the waiting area (Williams et al., 2012a). Patient flow analysis could help designers to avoid the waste of space, which can be used to store wheelchairs or provide humanized facilities (Ai et al., 2016).

Providing evidence for space allocation decision

A hospital is a system composed of interrelated facilities. The locations of the facilities in the building directly affect the operational efficiency of the hospital. Building layout decisions can be made quickly and scientifically by mathematical optimization or artificial intelligence based on patient flow data. However, architectural design can never be defined as a pure mathematical optimization problem, it is more closely related to human feelings and experience. Therefore, recent studies have gradually returned to the essential concern of architectural design. In these literature, patient flow analysis combined with subjective opinions of doctors, nurses and patients has been applied to the studies of layout design of diagnosis and treatment units (Karvonen et al., 2012), emergency departments (Jessome, 2020; Freihoefer et al., 2007; Rismanchian & Lee, 2017), and waiting space (Vos et al., 2007).

Conclusion

This paper presents a survey of literature on applying electronic health record to understand patient flow pattern and bottlenecks in healthcare facilities. This paper reveals that a large number of related studies has been conducted in order to decide space size and allocation in hospitals. The various investigations has indicated that big data analysis is particularly valid for size prediction, layout evaluation and optimization. The literature observations suggest the necessity to develop a comprehensive framework to guide relevant studies using a diversity of big data resources in healthcare facility studies.

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