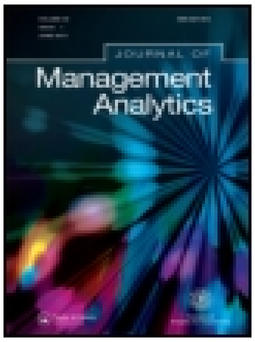

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Healthcare data analysis system for regional medical union in smart city

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Regional medical unions are practical approaches to deal with the cases that patients crowd in *Grade 3 Class A* general hospitals in metropolitan cities such as Shanghai, in China. However, electronic medical data analysis exists challenges when patients are referred among different hospitals in the regional medical unions during treatment procedures. In smart cities, demands for medical services provided by smart devises, complicate the environment of medical data analysis. In order to tackle the above problems, in this paper, a healthcare data analysis system for regional medical union is designed to support doctors from different hospitals to assess health conditions of patients in an overall data view. Behaviour patterns are mined from physiological index values. Tags are generated from social networks data to find the hot topics concerned by people living in common region. Experiments are given to illustrate the feasibility of the system in supporting healthcare data analysis.

Keywords: smart healthcare; electronic healthcare records; behaviour pattern mining; regional medical union

1. Introduction

Regional medical union is a kind of new medical service model to handle the problem of seeing doctor difficult in China nowadays. Due to the lack of medical resources, such as excellent medical experts, expensive medical apparatus and instruments, people would like to go to *Grade 3, Class A* general hospitals in metropolises, such as Beijing and Shanghai to seek high-quality medical services. The believing that *Grade 3, Class A* hospitals will guarantee the disease curing leads to the uneven distribution of medical service demands among the healthcare service providers in big cities. For example, in Shanghai, the daily amount of outpatients of *Southern Division of Renji Hospital* in *Pujiang Town*, Shanghai is up to over 8000 from year of 2012. Outpatients have to wait in long queues and time to see the doctors in such *Grade 3, Class A* general hospitals like *Southern Division of Renji Hospital*. On contrary, the daily amount of outpatients of community health service centres in area such as *Pujiang Town* where *Southern Division of Renji Hospital* locates, is much more less than expected, because that local residents believe that doctors in community health service centres are not as the same excellent as those in *Grade 3, Class A* general

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hospitals. Therefore, the cooperation of *Grade 3, Class A* general hospitals, such as *Southern Division of Renji Hospital* with community health service centres, such as *Pujiang* community health service centre, by means of regional medical union is a practical and possible approach to integrate regional medical resources and re-allocate outpatients especially aged patients who have chronic diseases among different levels of medical service providers.

With the implementation of regional medical union, chronic diseases patients could go to see a doctor in general hospitals at the first time when the disease is diagnosed or the treatment needs to be adjusted, then go to see a doctor in community medical service centre for regularly monitoring or medicine taking. With the convenient referring of patients between different levels of hospitals, the workload of general hospitals could be eased and the medical service resources of the community centres could be utilized as much as possible.

However challenges exist when patients try to obtain medical services in regional medical unions. One challenge is how to share personal healthcare data across different hospitals in medical unions. At present, medical records are usually collected in hospital information systems (HISs) when patients go to hospitals. Most of these HISs are developed and maintained by hospitals independently leading to isolated electronic medical records (EMRs) distributed in separated HISs. It is critical to find a solution to integrate EMRs from viewpoints of patients.

Another challenge is how to integrate daily health monitoring data into regional medical service delivery process. Smart devices could collect daily behavioural data, which affect personal health states. However, these monitoring data are usually recorded out of hospitals by devices, such as home blood pressure (BP) monitor. In traditional HISs, there are not interface for users' to submit their home collected data.

In order to deal with the above challenges, the design of healthcare data analysis system for regional medical unions are studied focusing on how to fulfil heterogeneous healthcare data fusion and sharing based on semantic processing and mobile computing technology.

The remainder of the paper is organized as follows. Section 2 presents a literature review about healthcare management and medical data analysis. Section 3 briefly describes the organizational model of regional medical union from viewpoints of human resources and patients allocation, while Section 4 discuss in details the components of healthcare data analysis system which enable EMR sharing in smart cities. Experiments are conducted and discussed to illustrate the process of data analysis in Section 5, while Section 6 presents the conclusions, suggesting further research work.

2. Background and related work

We review some related works in this section, which consists of two parts. The first part describes some models of health service that can be used or related to our goal. The second part describes EMRs application, especially for smart cities in the literature and discusses why these applications fail to fully fit our goal.

National Health Service (NHS) in UK is one of the world's largest publicly funded health service systems. NHS is patient-centred and emphasis Predictive, Preventive and Personalized Medicine elements (Grosios, Gahan, & Burbidge, 2010). In UK, residents need to register with a local general practice (GP) and should go to see the GP in the Surgery or Health Centre if people fell ill or worry about their health states. The work presented in Jasper Vink et al. gets the conclusion that referral process involves too many steps causing delays in access to consultations with hospital specialists so that more patients wait long time for key diagnostic tests (2016). GPs are considered playing more important leadership roles in the clinical commissioning groups for improve the quality of medical services providing of NHS. The qualitative multi-case study research shows collaborative style of leadership is perferred by GPs to form new alliance between clinicians and managers (Marshall, Holti, Hartley, Matharu, & Storey, 2018). It means that in primary care process collaborative decision-making is expected to be conducted by different medical specilists.

In recent years, GPs have been widely discussed in China to form new model of medical service delivery mode called regional medical union. Regional medical union in China, in the way of its operation, is similar to that of NHS in UK. It is considered an effective approach to integrate local medical resources (Lin & Dong, 2017; Zhang, Gu, Wang, & Wei, 2014). Unfortunately, the process of referral is not convenient for both hospitals and patients involved in regional medical unions. The research presented by Xu and Yu emphasizes that the construction of two-way referral mechanism and the development of advanced HISs are effective measures to improve the acceptance of regional medical unions (2015). Research results show that the service delivery mode of medical union is highly acceptable by patients of chronic diseases such as diabetes (Huan et al., 2018). Residents who have diabetes are willing to sign contracts with family doctors who belong to regional medical unions. With the interruption of family doctors into daily diets, the index values such as fasting blood glucose, blood lipid parameters, BP and body mass index (BMI) are improved compared to those who did not sign contracts with home doctors. It could be concluded that regional unions are suitable for medical service delivery in China, but it is still in the beginning stage of redesign for medical service process. More works need to be done about, for example, how to deal the situation of emergency medical, or how to cooperation and share information among different hospitals efficiently. In our research, the whole clinic process of medical service delivery for regional medical unions is proposed handling both chronic and emergent/severe disease treatment.

In addition to the redesign of the clinic process for regional medical unions, with the rapid deployment of networked infrastructure and wide usage of smart devices, smart cities have been a new paradigm of city life (Ianuale, Schiavon, & Capobianco, 2015) that affectting ways of healthcare data analysis. Data in terms of healthcare, environment, entertainment, transportation and energy are collected in real time via large number of sensors, leading to the applications of online healthcare monitor, diagnosis or medicine trade in smart cities. Issues of security, privacy and data exchange have been the challenging tasks in smart city applications (Parah, Sheikh, Akhoon, & Loan, 2018). For instance, the disunity of the standard system of the Internet of Things (IoT) technology is considered the drawbacks to hinder the adoption of smart community medical service in China. Suggestions are proposed by Zhen-Hua (2017) that governemt should develop and unify the technical standards for IoT devices. Besides unifying the technology standards, it is also important to propose technical apporaches to integrate applications or systems automatically. In this paper, method of data fusion is explored to integrate data tranferred from various IoT devices using semantic network technology.

In regional medical unions the accessing and mining of integrated medical records are critical to GPs for clinical decision-making. EMR systems have been considered as a rather convenient method to collect clinic information especially in rural or remote areas where lack of adequate medical specialists (Srinivasa, Anupindi, & Kumar, 2018). However, the adoption of EMR systems by doctors and physicians are lower than expected because doctors and physicians feel it is trivial to input the information manually. Meanwhile, the distributed EMR systems often cut off critical information or fail to integrate heterogeneous data from different hospitals for data mining.

Therefore, in order to automatically collect states of physical objects in real time, smart devices are used to record physiological indexes (Liu, Stroulia, Nikolaidis, Miguel-Cruz, & Rincon, 2016; Marakhimov & Joo, 2017). Because IoT devices in smart city applications have composed a complex pervasive computing network, computing architecture design and high-level abstracted data definition are essential to system development (Liao & Fu, 2018). Service computing and fog/cloud platforms are used to process big data ubiquitously among agents (Truong, Narendra, & Lin, 2018). Rahmani et al. proposed a fog-computing-based method to construct gateways between mobile sensors and Internet to translate sensor data from one type to another (2018). In their research, Pramanik, Lau, Demirkan, and Azad, (2017) proposed a conceptual platform using big data analysis and smart devices to provide smart healthcare. The main components in the platform are suitable to be used for regional medical unions considering the requirements of health monitoring through smart devices.

Meanwhile, in order to integrate distributed medical records correctly for better supporting medical specialists to make clinic decisions, big data mining methods have been proposed in healthcare as well as other industrial fields (Cheng, Chen, Sun, Zhang, & Tao, 2018; Duan & Binbasioglu, 2017). For example, in E-business application, spatiotemporal data that describe the context of objects being analysed are involved to combine with semantic similarity calculation aiming at improving the accuracy of venues recommendation (Margaris & Vassilakis, 2017). Similarly, for EMR mining applications, semantic technologies, such as ontology and linked data model are widely explored for big data mining. Ontology is extracted and constructed from the rational databases of HISs. Then data warehouses can be designed based on the ontology for intelligent clinic decision-making support (Xu et al., 2016). In order to enhance the semantic description of EMRs, open linked databases are adopted to link meta-data of HIS databases with out-of-hospital knowledge so that the meaning of the medical data could be explained automatically for data integration (Jiang et al., 2014).

From the above literature analysis, it could be seen that IoT network and large scale of online smart devices bring opportunities to collect healthcare data accurately and real timely via constructing distributed IoT systems. However because of the complexity in the process of cooperative medical service delivery, the requirements of data analysis for regional medical unions are not completely satisfied by the above methods to fuse smart device data into medical records in two aspects (Alyass, Turcotte, & Meyre, 2015).

(1) Data fusion does not directly display behavioural patterns of patients to GPs.
(2) Existing methods do not consider the factor of social media that could reflect and even affect the conditions of residents' health conditions.

The main contribution of this paper is that, aiming to improve the efficiency of medical service delivery and the medical resource availability of the whole society, the regional medical union mode in China is explored. A redesigned clinical process is proposed in this paper to improve the collaboration among general hospitals and community medical centres. Furthermore, the medical data analysis method proposed in this paper considered not only the integration of EMRs from different hospitals but also the mining of the behaviour patterns from data of smart devices and social media. Differ from traditional EMR systems aiming at clinic decision-making support, the proposed technical architecture and the implemented prototype of this paper are patient-centred and healthcare monitor targeted, which will better meet daily healthcare requirements of local residents especially for aged patients with chronic diseases.

3. Organizational model of regional medical union

Organizational model of regional medical union is shown as follows (see Figure 1). Differing from traditional medical service process, which is provided by isolated

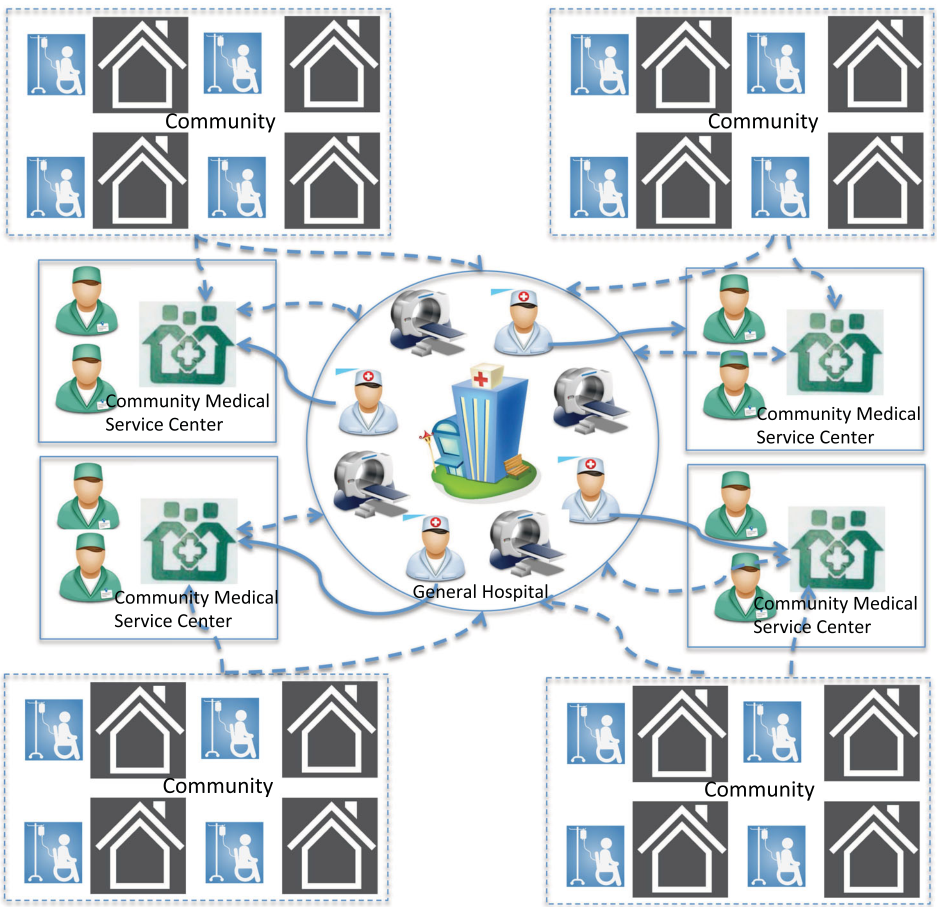

Figure 1. Organizational model of regional medical union.

hospitals, in regional medical unions doctors would jointly make treatment plans for patients, during which doctors in high-level hospitals would have more power to dominate the treatment plan decision.

In Figure 1, from the viewpoint of human resource management, there are two kinds of medical professional staff will be involved in regional medical unions. They are specialists in general hospitals and GPs in community medical centres. These medical professional staffs are virtually jointed together. Specialists in general hospitals work in *Grade 3, Class A* general hospitals, at the same time in united community medical centres. At most weekdays, specialists work in general hospitals to process emergency medical situations or treat seriously illnesses. In at least one weekday, specialists work in community medical services centres, guiding GPs to make treatment plans for patients in community medical service centres. The main tasks of GPs will mainly focus on chronic diseases or minor illnesses and give healthcare suggestions to residents who live nearby.

In Figure 1, dotted arrows represent the activity flows of patient, while solid arrows represent medical experts flowing from higher level general hospital to lower level general hospitals or community medical service centres.

For residents who need to see the doctors, they will have two options to choose a medical unit to make their appointments. One option is going to general hospitals, where there are usually more experienced specialists. But usually general hospitals are more crowded. Another option is going to community medical service centres, where GPs may be less experiences or abilities in treating seriously diseases. But usually community medical service centres are less crowded.

The main target of regional medical union is to guide patients to make reasonable decision in making their appointments with doctors. Because people usually cannot professionally assess the severity of their illness by themselves, but if all residents who live in the communities go to see GPs when they encounter health problems, community medical service centres will not have enough GPs to meet the demands of residents. Therefore, in Figure 1 patients are expected to go to see the doctors in general hospitals when they encounter one health problem the first time. Then diagnosis and treatments will be given by doctors in general hospitals. After the health conditions of the patients become stable, they could be referred to community medical centres for a period of recovery. If the conditions of the patients in community medical centres become serious, they could be immediately re-referred to general hospitals for further treatments.

Figure 2 shows the process that outpatients acquire medical services in regional medical unions. It could be noticed there exist at least three paths from the beginning outpatients make appointments with doctors to the end diseases are treated properly.

One path (*path 1*) starts from making appointment with doctors in community medical service centres. If GPs could handle the diagnosis and treatments, the clinic processes will end at outpatients going back home.

Another path (*path 2*) also starts from making appointment with doctors in community medical service centres. If GPs feel the severities or the complexities of the diseases go beyond their abilities or experiences, they could choose asking for group consultations from *Grade 3, Class A* hospitals or transferring patients to *Grade 3, Class A* hospitals. If group consultations could get proper diagnosis and treatments, outpatients will stay at community medical service centres to finish the clinic process.

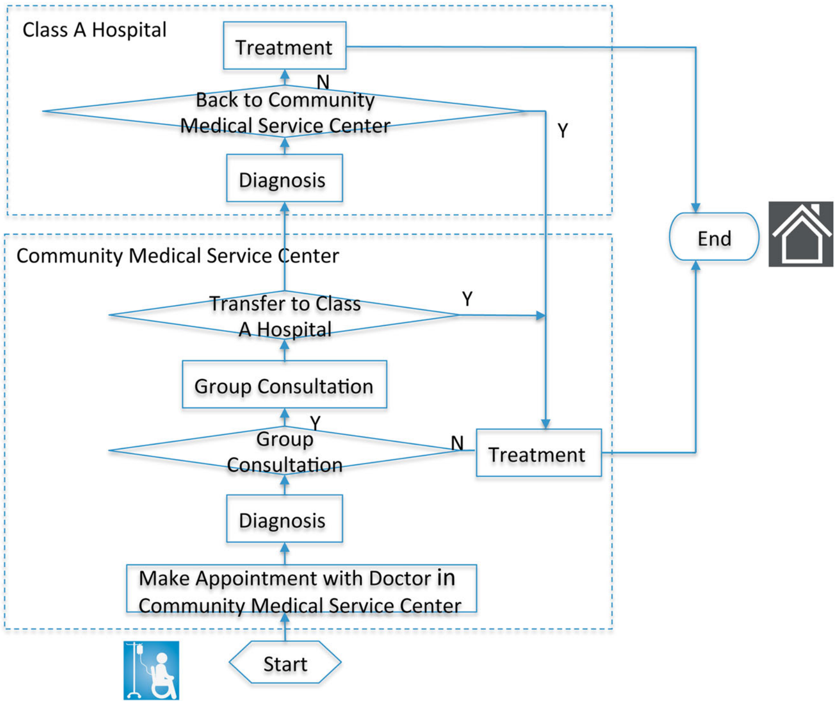

Figure 2. Process diagram of outpatients visiting doctors in regional medical union.

The third path (*path 3*) starts from patients being transferred from community medical service centres to *Grade 3, Class A* hospitals. Then the patients will be treated at *Grade 3, Class A* hospitals. After health states becoming stable, patients will return to community medical service centres for further recovery or back home if the diseases are cured.

If without regional medical unions, *path 2* and *path 3* will take a longer time for patients requiring group consultations or conducting transfer between different hospitals. On contrary, in regional medical unions, group consultations and patient transfers will be more quick and flexible if agreements are signed among these medical service providers in advance.

By present, it is still in the beginning stage for regional medical unions being applied in practice in China. When people feel sick, general hospitals are the first choice in most situations no matter how far or crowded these hospitals are, because most patients have not the ability to determine the severity of the diseases. If they go to community medical centre, it would be trouble if they need to be transferred to general hospitals because these medical serve agents are independent from each other without regional medical unions. On the contrary, within regional medical unions, agreements would be achieved in advance about free transferring and medical data sharing between general hospitals and community medical centres as shown in Figure 2. Therefore the medical service processes for regional medical unions have the following advantages compared to traditional medical service mode without regional medical unions.

(1) From the viewpoint of performance of medical resource utility, regional medical unions would be more efficient. Without the union of the general hospitals and community medical centres, people dislike go to community medical centres. Doctors in community medical centres often have few patients to treat. The distribution of the number of the patients between general hospitals and community medical centres is rather unbalanced. In regional medical unions, community medical centres play the roles to assign patients to general hospitals so that the workloads between general hospitals and community medical centres would be adapted to a reasonable distribution to improve the utility of medical resources.

(2) From the viewpoint of patient satisfaction, people will have more probability to get higher quality medical services in regional medical unions. Professional staffs in community medical centres will help patients to determine the severity of the diseases and make decision whether transferring to general hospitals or not. Because the medical data are freely shared between general hospitals and community medical centres, it will be convenient for patients to transfer among hospitals. In addition, patients could be better cared when they are transferred from general hospitals back to community medical centres in recovery stage. Therefore, in regional medical unions, the patient satisfaction will be improved by the cooperation of doctors from both general hospitals and community medical centres.

4. Prototype of healthcare data analysis system

In order to support the task of healthcare data analysis for regional medical union shown in Figure 2, a prototype of healthcare data analysis system is designed, as Figure 3 showing the technical architecture of the prototype. In Figure 3 clinic decision are supported by two types of information. One type of data is the electronic health record that describes the symbols, diagnosis and treatment plans that patients are undergoing. The other type of data is the personal health personas combined with individual health behaviour patterns.

In Figure 3, patients of regional medical unions may be referred frequently between general hospitals and community medical centres so that the EMRs are collected in distributed HISs. Middle software needs to be implemented to extract and load clinic data from different databases to form patient-centred medical records.

One of characteristics of residents in smart cities is the using of smart devices such as wrist straps to monitor daily physiological indexes, and using of social media such as *Wechat* to follow the issues of health. In the scenario shown in Figure 3, the individual daily health monitoring data and social network information are analysed and displayed to doctors for references in treatment plan making.

The technical architecture of the healthcare data analysis system for regional medical union is shown in Figure 4.

In Figure 4, the system is designed including data acquisition, data storage, data analysis and application interaction modules.

Data acquisition module accesses wearable devices such as bracelet, bathroom scale through identity authentication to gain the daily health monitoring data. Medical history records are transferred between hospitals in the regional medical

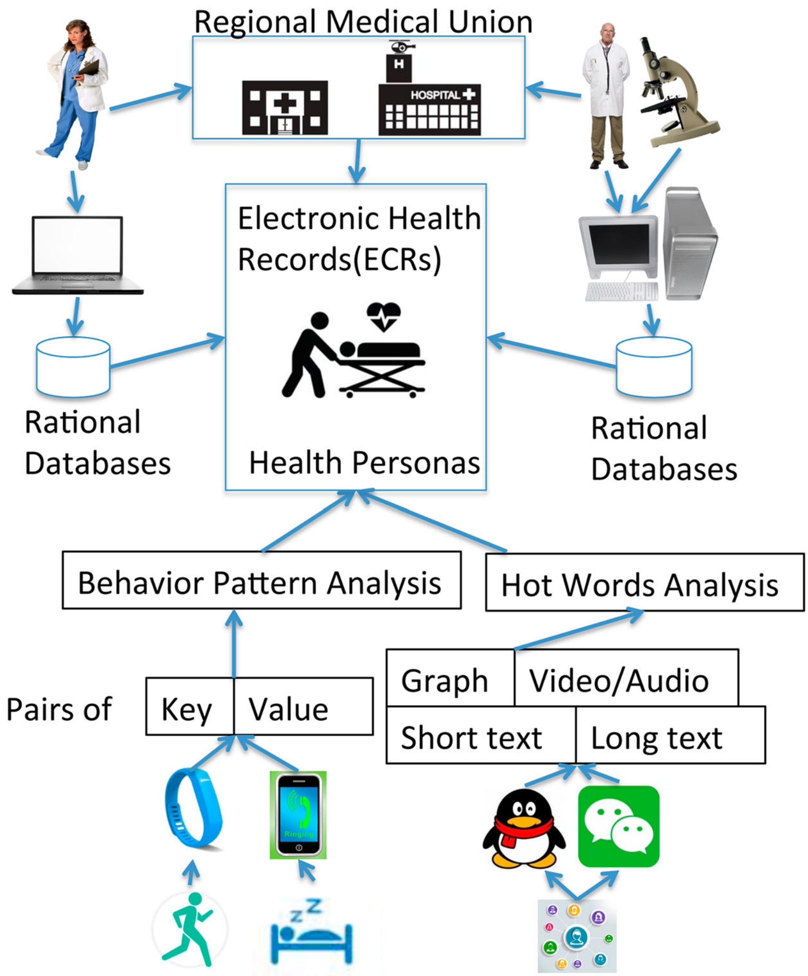

Figure 3. Scenario of the healthcare data analysis for regional medical union.

union with the approval of the patients. Web crawler is integrated in the module to collect Social media data for analysis of regional hot concerned topics. In addition to data collection, data clearing is also included in the module for abnormal data processing and data normalization.

Data storage module includes meta-data server named as *NameNode* and transaction data server named as *DataNode*. Meta-data server *NameNode* is the core component managing meta-data, such as name space, and responding to users' requirements. Healthcare data of patients are stored in data servers. The advantage of the separation of meta-data and healthcare data in the architecture design is that it is more extendible in the scale of processed healthcare data. With the growth of healthcare data scale, the system could be extended via increasing the number of data servers.

Data analysis module integrate various data sources such as physical exercises, daily diet, emotional feel, clinical history records and so on for data mining or tagging.

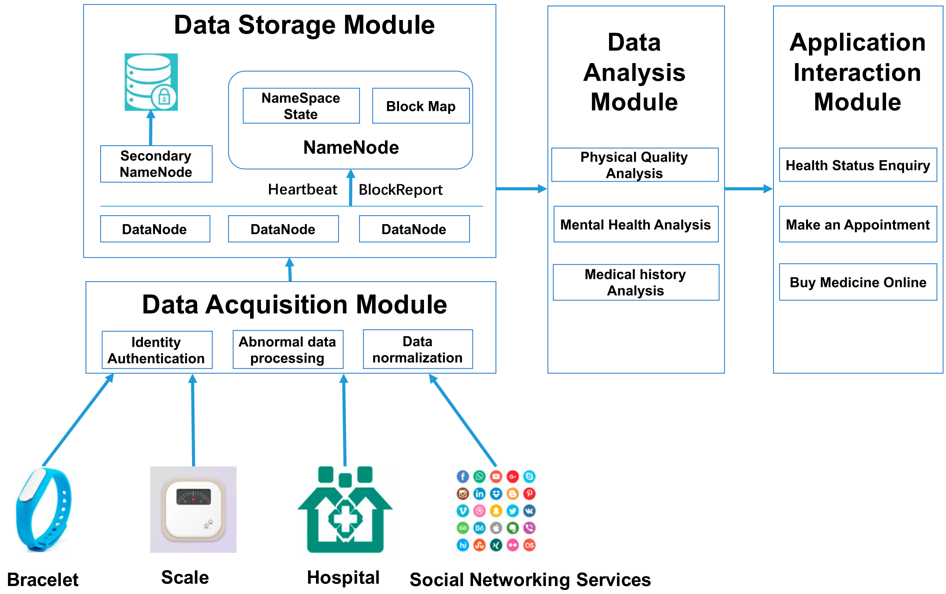

Figure 4. Technical architecture of the healthcare data analysis system.

In application interaction module, authorized doctors and patients can access medical historic records or assess individual health condition based on across hospital data sharing.

Because healthcare data that collected from different kinds of medical devices may be redundant, ambiguous and inconsistent, data heterogeneity is the challenge for data analysis in regional medical unions. We adopt semantic technology to fusion data collected from heterogeneous sources, as shown in Figure 5.

In Figure 5, distributed smart devices upload different data, for example, *device A* uploads data of {BMI, BP, Body weight, Walking step}, *device B* uploads data of {BloodP, Step}. In order to fuse data *Blood pressure* with *BloodP*, similarity in higher level from external open linked data by *Levenshtein distance* algorithm is calculated, shown as following.

$$\mathrm{lev}_{a,b}(i,\ j) = \begin{cases} \max(i,\ j), & \textit{if}\ \min(i, j) = 0, \\ \min \begin{cases} lev_{a,\,b}(i-1, j) + 1, \\ lev_{a,b}(i, j-1) + 1, \\ lev_{a,b}(i-1,\ j-1) + 1(a_i \neq b_j), \end{cases} & \text{otherwise.} \end{cases}$$

Two distribute data can be fused if the nodes in the linked data that they point to have the similarity value beyond threshold.

5. Experiments and discussion

In order to verify the feasibility of our proposed platform, we developed a prototype of mobile app for healthcare data analysis, in which the background side is developed

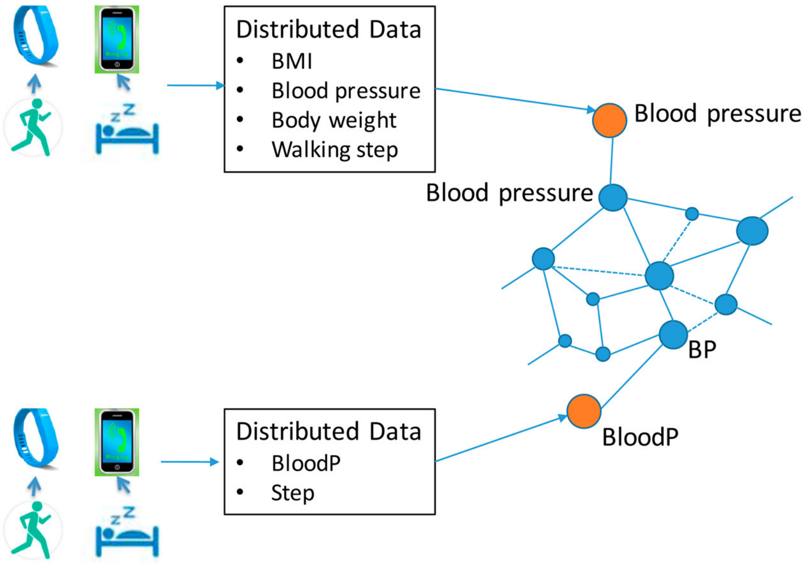

Figure 5. Process of data fusion for devices with heterogeneous data description.

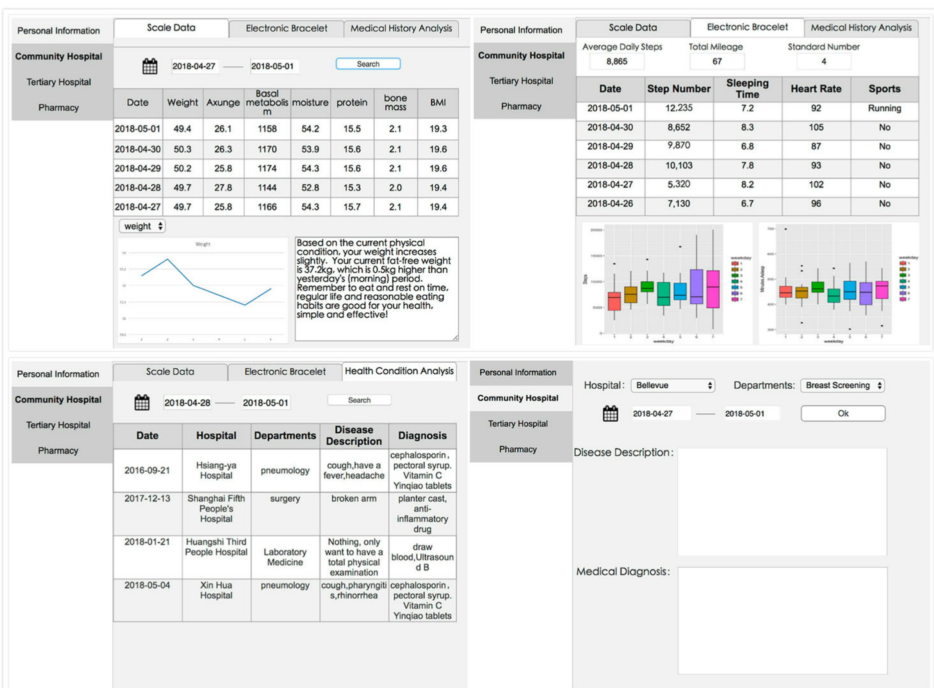

Figure 6. Interface of healthcare data analysis system.

using *Spring-mvc* platform, and the foreground side is developed using *Ionic* and *AngularJs* tools. One interface of the prototype is demonstrated as Figure 6.

In Figure 6, data from different devices such as scale, bracelet or different hospitals in medical unions could be integrated and displayed in the same screen for doctors to have a whole assessment of patients' healthcare status.

For example, individual behavioural pattern analysis could be derived from monthly or periodic data analysis, such as axunge and BMI which are recorded by smart body weight scales such as *PICOOC*, and daily walking steps which are recorded by smart phones. In the data analysis system, these data are exported into a XML file. Min–max normalization method is used to pre-process these collected data. Figure 7 shows tendency of axunge, BMI and walking step number.

In Figure 7, values of axunge, BMI and walking step number lasting two months are recorded and the changing tendency of these three indexes are demonstrated after Min–max normalization processing. It could be noticed in Figure 7 that walking steps have effects on the value of axunge and BMI which both reflect the per cent of fat in body. For example, between day 1 and day 16, there are two peak value of walking steps, then in day 16, the value of axunge get the lowest point meaning that after a period of walking exercise, the value of per cent of fat in body has decreased. Meanwhile, after day 16, the average of BMI is obviously lower than the average value before day 16, also meaning that the per cent of fat in body has decreased. Although exercise of walking could reduce the per cent of fat in body, it also could be noticed that the effect works after the exercise lasting a period of time. In Figure 7, the period of time is about two weeks. But when the walking steps decreased a little after day 16, the value of axunge and BMI increased a bit.

From the above analysis, it could be concluded that personal daily exercise could affect personal health conditions. So that it is necessary to involve the data collection and analysis of daily activities into healthcare monitoring systems. Therefore in our research, data of household smart devices such as scales and bracelets and data from social networks are involved into the healthcare data analysis as supplemental reference for doctors in regional medical unions to make diagnosis decisions or treatment plans.

In order to verify the usability of our method in regional group health status analysis, we conducted an experiment including 18 students lasting one month to collect data about day-to-day diet, BP and heart beating. At the end of the experiment, data of 14 students are complete and usable.

Diet data are one of key factors affecting health conditions but are difficult to be recorded because it would be boring tasks for people to record their diet every day for

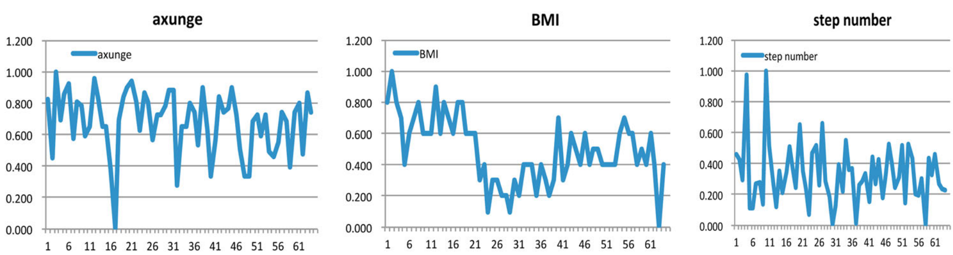

Figure 7. The tendency of axunge, BMI and walking step number.

each meal. Nowadays, lots people use intelligent mobile phones and are willing to share their diet particularly those delicious ones through social media, so that we developed an APP for students included in our experiment to upload the photos of their diet by smart phones. Totally 1710 pieces of diet photos are received from the students during the experiment. Deep learning algorithm *Resnet* was used to recognize the food in the photos and classify the diet into two types, which are meat food and non-meat food.

In this experiment, data of day-to-day physiological index such as BP, heart beat and weight are collected using sports wrist straps because sports wrist straps are popular now and many people like to use sports wrist straps recording their daily exercises and monitoring their health conditions. The goal of our experiment is to verify the probability of analysing diet data referring physiological index data through smart devices such as wrist straps and intelligent mobile phones.

Figures 8 and 9 show the collected data and the clustering results using *K*-means.

In Figures 8 and 9, it could be seen that 14 students are classified as 3 groups. The results mean that students in the same group have the similar characters in their daily diet and health conditions. We checked the healthcare status of these 14 students manually and found that students labelling "0" and "1" are boys, meanwhile "2" is girls. It could be concluded that roughly boys and girls are different in terms of diet and physiological index values. For boys, they are classified into two types maybe mainly because of their different weight.

In addition to daily diet habits, opinions and news around ones living or working areas also have significant impact on personal healthcare behaviours. With the development of Internet, more and more people express their feelings or concerns in social medias like micro-blog. We developed a crawler program together with searching Application Programming Interface provided by the company of *Sina* to collect and count the number of micro-blogs concerning hot-key words in certain districts.

We use crawler program to collect hot words from 1 July to 30 July 2017 in *Minhang* district, Shanghai in sports, health and diet fields, then we use *RelFinder* to access *DBpedia* to find the relationship between these popular words. If one word has no relationship with other words, we will drop it. Finally, we use data visualization tools to show these relationships (see Figure 10).

In Figure 10, we can see that the hot words are divided into three different topics, which are health, sports and diet. Because one single micro-blog often contains only

weight	BMI	BF	meat/total	mor_high_pressure	mor_low_pressure	aft_high_pressure	aft_low_pressure	high_heart	avg_heart	label
67.17	18.83	19.83	0.52	116.00	74.59	117.38	75.25	102.53	79.47	0
61.70	19.50	16.82	0.45	120.97	75.97	116.70	73.17	90.27	86.83	0
54.37	18.67	15.00	0.47	121.81	77.56	121.93	76.56	93.59	77.11	0
62.02	19.38	13.88	0.30	120.32	74.53	118.89	74.68	93.89	75.68	0
74.50	26.37	27.97	0.63	121.97	77.30	121.18	77.39	97.58	73.30	2
65.53	20.85	24.22	0.40	117.96	73.65	118.74	75.74	87.65	72.61	2
75.58	26.12	23.03	0.61	115.87	73.68	112.39	71.39	77.39	66.29	2
49.42	19.32	25.27	0.31	116.37	72.57	116.13	72.47	92.67	76.23	1
47.17	17.93	23.23	0.44	114.45	73.74	114.39	72.13	93.42	77.16	1
52.12	19.60	29.70	0.86	114.73	72.27	117.53	72.33	92.80	72.80	1
52.67	20.52	26.75	0.26	115.94	71.33	112.82	70.64	93.97	61.64	1
52.02	20.32	27.13	0.39	115.74	72.10	109.84	68.45	98.13	60.94	1

Figure 8. The collected data and the clustered results using *K*-means algorithm.

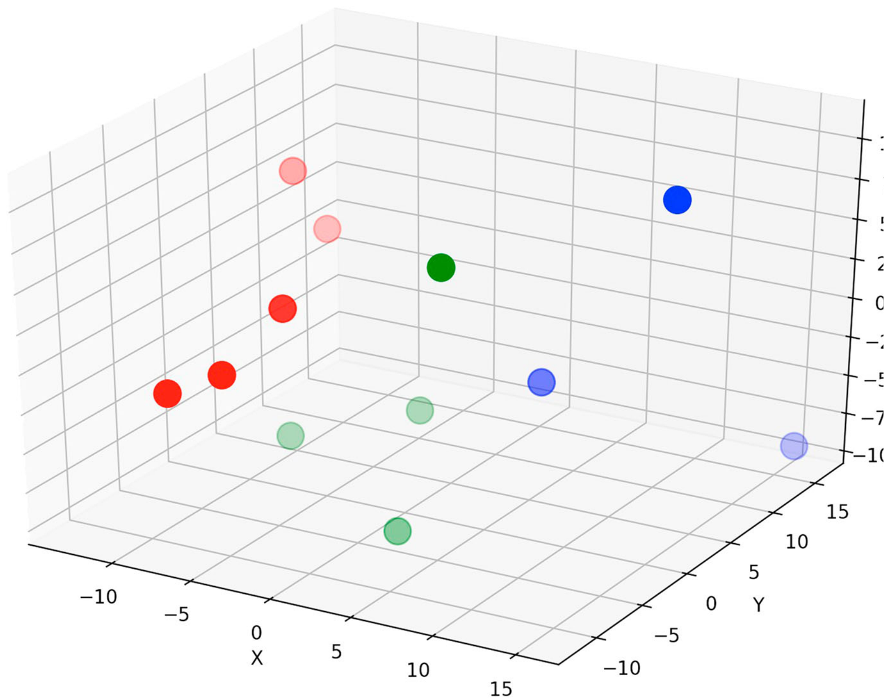

Figure 9. Clustered results showing by *K*-means algorithm.

few popular words, it is hard for us to deduce the relationship between them. However, by using open linked data sets, we can get the label of different resources and finally find the relation between them.

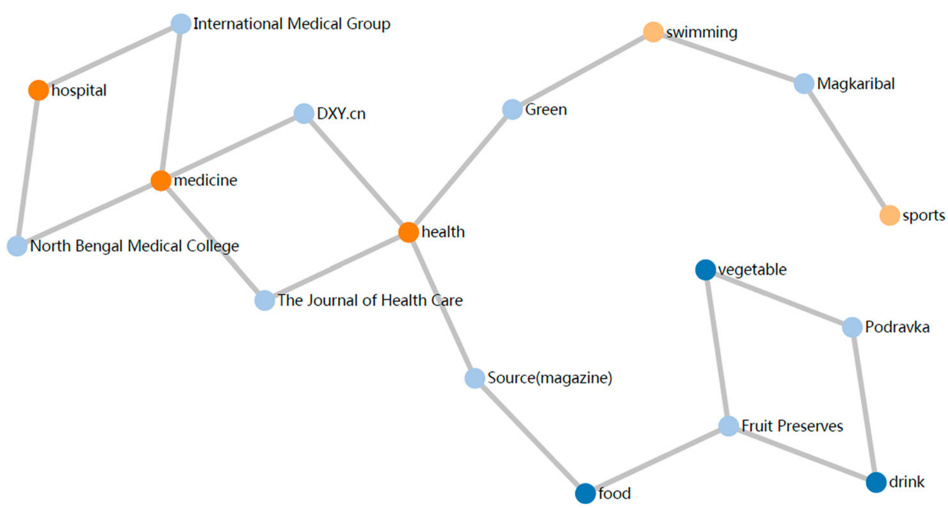

Figure 10. Hot words from local social media and their relationship.

6. Conclusion and future work

It has been known that seeing doctor is difficult in China, especially in metropolis such Shanghai and Beijing because too many people would like go to see the doctors in general hospitals directly when they feel ill or worry about their health. Regional medical unions are solutions to solve the problem that patient flows distribute unevenly in these big cities. The contributions of this research are follows.

Firstly the organizational model of regional medical union is discussed. In regional medical unions, specialists work with GPs to make treatment plans and dominate the process of treatments. Patients are encouraged to go to general hospitals when they encounter health problems, but would be better referred to GPs in community medical centres for recovery.

Secondly in order to support the cooperation of specialists in general hospitals and GPs in community medical centres, a health data analysis platform is proposed to provide integrated patient-centred EMRs, together with individual activity pattern and local social media hot words to support clinical decision-making. The technical details of the platform are discussed. Prototype is developed to ensure what functions should be designed to effectively support the cooperation of specialists and GPs.

Finally, several experiments are conducted to show the analysis of individual activity pattern from smart devices. Health data from smart body weight scales and sport data from smart phones are visualized together to illustrate the trend of physiological indexes. Hot words are obtained from local social medias. The relationships among these hot words are linked to reflect the concerned issues potentially matter regional health problems.

One future work will be the construction of more accurate models of behaviour pattern and hot words mining for big medical data. Another future work is to design appropriate fog-cloud architecture for regional medical unions to properly balance data processing workloads between smart medical devices and HISs.

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References

Alyass, A., Turcotte, M., & Meyre, D. (2015). From big data analysis to personalized medicine for all: Challenges and opportunities. *BMC Medical Genomics*, *8*(1), 613.

Cheng, Y., Chen, K., Sun, H., Zhang, Y., & Tao, F. (2018). Data and knowledge mining with big data towards smart production. *Journal of Industrial Information Integration*, *9*, 1–13. doi:10.1016/j.jii.2017.08.001

Duan, L., & Binbasioglu, M. (2017). An ensemble framework for community detection. *Journal of Industrial Information Integration*, *5*, 1–5. doi:10.1016/j.jii.2017.01.001

Grosios, K., Gahan, P. B., & Burbidge, J. (2010). Overview of healthcare in the UK. *EPMA Journal*, *1*(4), 529–534.

Huan, H., Fan, Y., Yang, J., Jiang, S., Li, N., & Liu, S. (2018). Effect of "1+1+1" family doctor service delivery mode on community-based diabetes management (in Chinese). *Chinese General Practice*, 21(9), 1075–1079.

Ianuale, N., Schiavon, D., & Capobianco, E. (2015). Smart cities and urban networks: Are smart networks what we need? *Journal of Management Analytics*, *2*(4), 285–294. doi:10.1080/23270012.2015.1023856

Jiang, L., Li, L., Cai, H., Liu, H., Hu, J., & Xie, C. (2014). A linked data-based approach for clinical treatment selecting support. *Journal of Management Analytics*, *1*(4), 301–316. doi:10.1080/23270012.2014.988762

Liao, C.-F., & Fu, H.-Y. (2018). Spatial-aware service management in a pervasive environment. *Service Oriented Computing and Applications*, *12*(2), 95–110.

Lin, H., & Dong, J. (2017). Internet plus healthcare alliance helps implementing hierarchical healthcare system (in Chinese). *Chinese Hospitals*, *21*(5), 52–53.

Liu, L., Stroulia, E., Nikolaidis, I., Miguel-Cruz, A., & Rincon, A. R. (2016). Smart homes and home health monitoring technologies for older adults: A systematic review. *International Journal of Medical Informatics*, *91*, 44–59.

Marakhimov, A., & Joo, J. (2017). Consumer adaptation and infusion of wearable devices for healthcare. *Computers in Human Behavior*, *76*, 135–148.

Margaris, D., & Vassilakis, C. (2017). Exploiting Internet of things information to enhance venues' recommendation accuracy. *Service Oriented Computing and Applications*, *11*(4), 393–409.

Marshall, M., Holti, R., Hartley, J., Matharu, T., & Storey, J. (2018). GP leadership in clinical commissioning groups: A qualitative multi-case study approach across England. *British Journal of General Practice*, *68*(671), e427–e432. doi:10.3399/bjgp18X696197

Parah, S. A., Sheikh, J. A., Akhoon, J. A., Loan, N. A. (2018, March 8). Electronic health record hiding in images for smart city applications: A computationally efficient and reversible information hiding technique for secure communication. *Future Generation Computer Systems*. doi:10.1016/j.future.2018.02.023

Pramanik, M. I., Lau, R. Y. K., Demirkan, H., & Azad, M. A. (2017). Smart health: Big data enabled health paradigm within smart cities. *Expert Systems with Applications*, *87*, 370–383.

Rahmani, A. M., Gia, T. N., Negash, B., Anzanpour, A., Azimi, I., Jiang, M., & Liljeberg, P. (2018). Exploiting smart e-health gateways at the edge of healthcare internet-of-things: A fog computing approach. *Future Generation Computer Systems*, *78*(Part 2), 641–658.

Srinivasa, K. G., Anupindi, S., & Kumar, A. (2018). Analytics on medical records collected from a distributed system deployed in the Indian rural demographic. *Journal of Management Analytics*, *5*(1), 54–72. doi:10.1080/23270012.2018.1433085

Truong, H.-L., Narendra, N. C., & Lin, K.-J. (2018). Notes on ensembles of IoT, network functions and clouds for service-oriented computing and applications. *Service Oriented Computing and Applications*, *12*(1), 1–10.

Vink, J., Oyewole, F., Jamshaid, S., Patel, R., Froogh, Z., & Bhambra, M. (2016). Medical student perspective: Reducing patient waiting times in the UK National Health Service. *Journal of Multidisciplinary Healthcare*, *9*(1), 207–209.

Xu, B., Xu, K., Fu, L., Li, L., Xin, W., & Cai, H. (2016). Healthcare data analytics: Using a metadata annotation approach for integrating electronic hospital records. *Journal of Management Analytics*, *3*(2), 136–151. doi:10.1080/23270012.2016.1141331

Xu, B., & Yu, L. (2015). Analysis of the process of regional medical union development difficulties. *Medical Innovation of China*, *12*(09), 111–114.

Zhang, L., Gu, M., Wang, X., & Wei, K. (2014). Development strategy on regional medical association (in Chinese). *Chinese Health Quality Management*, *21*(2), 74–76.

Zhen-Hua, L. (2017). *Research on the current situation and countermeasures of smart community medical service system in China*. 3rd annual international conference on management, economics and social development (ICMESD 2017), advances in economics, business and management research (Vol. 21, pp. 361–364). doi:10.2991/icmesd-17.2017.67