Intelligent Knowledge Management System for Distributed e-Home Healthcare

U-Hou Choi, Jia-Li Ma, Ran Guo, and Ming-Chui Dong

***Abstract*—With the functions of on-site multi-vital-signs acquisition, real-time transmission, diagnosis and detailed interpretation, an embedded-link e-home healthcare system on mobile devices brings lots of conveniences for prevention and detection of cardiovascular diseases (CVD). Due to the intrinsic source restriction in those devices, a backyard remote uplink, update and synchronize (UUS) system is imperative to manage the uplinked requests from local mobile devices and feedback promptly the update package. To guarantee the efficiency and availability of UUS when facing thousands of concurrent requests and user clients, an intelligent knowledge management system (KMS) becomes the most significant concern. In this paper, a dedicated customized knowledge base (KB) with simplicity, conformity, extensibility, and flexibility is proposed to release the burden on UUS by reduction of unnecessary help requests. In addition, an intelligent KB update scheme with delta-change and master-slave approach is pioneered to perform automatic rules update with minimum dataflow while ensuring the reliability and safety of overall system. Via the constructed KB, an intelligent diagnosis system is implemented to provide detailed diagnostic results as well as comprehensive pathological warning messages.**

***Index Terms*—CVD diagnosis, distributed e-home healthcare, knowledge base design, knowledge management system, rule update.**

I. Introduction

The continuously growing death due to cardiovascular diseases (CVD) makes it the leading cause of death over the world. World Health Organization reported that an estimated 17 million people died from CVD in 2008, representing 30% of all global deaths and will increase to 23 million by 2030 [1]. Although early detection and timely treatment can prevent CVD efficiently, it highly increases demands on healthcare services and burden on hospitals and medical personnel. As a solution, intelligent mobile devices, wireless communication technology, and remote healthcare architectures are introduced to target transforming hospital-rescue-centered healthcare scheme to patient-prevention-centered approach [2]-[8].

Fig. 1 describes the architecture of distributed e-home healthcare platform as presented in [9]. The overall system consists of three sub-systems, namely upstream (hospital server), midstream (patient local computers), and downstream (embedded-link devices, e. g. smartphone, tablet, or personal digital assistant). Multi-vital-signs such as electrocardiography (ECG), sphygmogram (SPG), and heart sound (HS) are acquired and transmitted to wireless-linked midstream and/or downstream for further analysis, interpretation, and diagnosis to procure the results of health status and pathological warning messages. Whenever it encounters doubt regarding the results or failed diagnosis caused by insufficient knowledge base (KB) in lower streams, users can request remotely-linked upstream for help by triggering the customized disease-driven assistance system, i.e. the uplink, update and synchronize (UUS) system. The server in upstream is equipped with abundant KB rules and comprehensive data base (DB) storing all user clients' information, which is able to recognize and feedback individually the absent KB rules in user client for update.

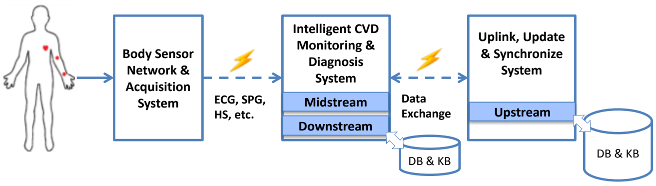

Fig. 1. Systematic architecture of distributed e-home healthcare platform.

Acting as the backend support and remote assistance system, UUS is the key significance to cover the deficiency and limitation in lower streams and satisfy various users' demands, thereby effectively supports the functionality of the overall distributed e-home healthcare system. However, several bottleneck problems must be solved to guarantee the availability and efficiency of UUS:

1) How to store sufficient rules in user mobile devices with limited resources?
2) How to design a customized KB in user devices and avoid the occurrence of diagnosis failure as much as possible?
3) How to realize KB update intelligently and automatically?
4) How to handle unexpected circumstances during update?

Tackling these problems, as first attempt among this world so far, a novel intelligent knowledge management system for distributed e-home healthcare application is proposed in this paper. With a well-designed KB framework and customized rules configuration, the resource-limited user devices are able to store adequate personalized knowledge rules, which will speed up the diagnosis, significantly increase the reliability of user client systems, and release the burden on uplinked server by reducing the amount of unnecessary help requests caused by diagnosis failure. Furthermore, an intelligent KB

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delta update scheme is also proposed to perform absent rules update individually and automatically with minimum dataflow, while the pioneered master-slave KB strategy ensures the reliability and safety of whole system. Finally, an intelligent diagnosis system based on the designed KB is constructed.

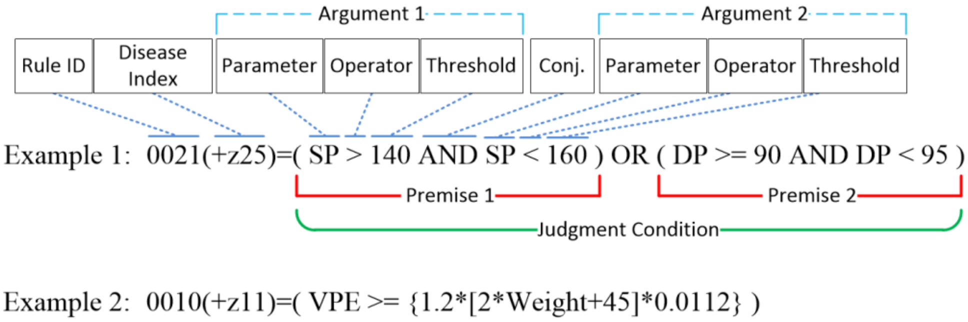

Fig. 2. Designed rule structure in cardiovascular diagnostic knowledge base.

TABLE I: CARDIOVASCULAR DISEASES RULES CLASSIFICATION

Name of Package		Description	Number of Rules
Basic Package		General rules for preliminary diagnosis of coronary heart diseases, valvular heart diseases, arrhythmia, cardiac failure, and hypertension	30
Extension Packages	Hypertension	Detailed diagnostic rules for hypertension	8
	Cardiac Failure	Detailed diagnostic rules for various types of cardiac failure	3
	Pulmonary	Diagnostic rules for pulmonary diseases, including congestion, artery diseases.	7
	Peripheral	Diagnostic rules for peripheral arterial diseases	6
	Viscosity	Detailed diagnostic rules for blood viscosity diseases and arteriosclerosis	9
	Microcirculation	Detailed diagnostic rules for microcirculation diseases	3

II. INTELLIGENT KNOWLEDGE MANAGEMENT SYSTEM

The proposed knowledge management system (KMS) consists of three parts. The first part is KB design including KB framework design and customization; the second part is intelligent KB update scheme design; the third part is diagnostic system design based on the constructed KB. Since the knowledge management in resource-limited downstream devices is more challenging than in midstream, this paper mainly focuses on the KB update scenario in downstream. Java Development Kit is chosen as the development platform due to its common adaptability on embedded-link devices, whereas the design methodology is also applicable for other software development platforms.

A. *Knowledge Base Design*

1) *Knowledge base framework*

The design of KB framework is the foundation of overall KMS and it should satisfy following technical requirements: 1) simplicity to store plenty of knowledge rules in limited file size with easy access format; 2) conformity to ensure all the rules in systematic and consistent structure; 3) extensibility to perform efficient knowledge update from server; 4) flexibility to better adapt to certain diseases by retrieving specific knowledge.

In the design, KB rules are written in machine language and stored as text form for easy access and process. As is illustrated in Fig. 2, the structure of KB rule is composed of three parts: rule identification (ID), disease index, and judgment conditions. Each rule starts with a unique ID ranging from 0000 to 9999. In the construction of disease index, the number following a “z” corresponds to certain unique disease while symbol “+”/“-” represents that the following judgment condition is for/against the listed diseases. A rule may contain several disease indices on event that they possess the same condition or symptom. With regard to judgment condition, multiple premises can be defined in the same rule with conjunctions and brackets “( )” added in between. Argument, as the basic component of premises, comprises a real value of certain biomedical parameter calculated from the site-sampled user’s vital signs, a threshold value which can be a single number or a curly brackets “{ }” quoted formula, and an operator to compare the two values. Two rule examples are given in Fig. 2, and we observe that in example 1 two premises are included and connected by a conjunction “OR” in between, whereas the rule in example 2 has only one premise with a formula as threshold value. Different brackets are employed to distinguish among formula, premises, and arguments. The calculating order of those brackets is also considered, i.e. contents within “[ ]” must be calculated prior to those inside “{ }” and “( )” goes last.

The proposed KB framework has several advantages: 1) straightforward to access with the text format applicable in various mobile devices as well as computers; 2) convenient to synchronize between servers and user clients with a consistent and unique rule ID allocation; 3) effortless to modify and update with an intelligible framework design; 4) resource saving with extremely small KB file size, e.g. one rule occupies approximately 60-300 bytes with varying complexity, implying that a KB file of 10,000 bytes can accommodate more than 100 rules on average.

2) Knowledge base customization

In user client devices, the diagnostic accuracy directly depends on the diversity of local KB rules, yet it is impossible to store all the useful KB rules in resource-limited mobile devices. Although users can turn to uplinked server for help in case of diagnosis failure and the server will feed back the precise diagnostic results, it is indeed troublesome and inefficient managing thousands of user requests at the same time. Therefore, a customized KB is imperative to satisfy various users' demands, guarantee reliability of user client systems, as well as release the burden on server through reduction of unnecessary help requests.

For customization, all the useful KB rules are divided into two categories: basic rule package and extension rule packages. The basic package contains all the common CVD diseases while extension packages include several rule packages of different disease categories, such as hypertension package and peripheral arterial disease package. At the startup of e-home healthcare system, each local platform is equipped with identical basic KB package and can be further customized by downloading various extension rule packages from the server according to user's diagnostic results or request. Table I lists the CVD rules classification applied in our system. With such a tailor-made light KB strategy, the source-restricted mobile devices are capable of providing preliminary diagnostic results for both normal and rare diseases efficiently.

The structure and customization of KB together strike a subtle balance between computation complexity and diagnostic accuracy, Hence, it not only adapts the source-limited embedded-link devices to diverse users but also dramatically reduces the occurrence of local devices diagnostic failure caused by absent relevant KB rules.

B. Intelligent Knowledge Base Update Design

1) Delta update scheme

In event of diagnosis failure caused by absent or outdated rules and demands for KB customization, users' may trigger the KB update process to seek help from the server. The typical flowchart of local KB update process in client device is depicted in Fig. 3. Firstly, a manual help request is transmitted to server to establish up-down communication link. Afterwards, the whole update process will carry on automatically and intelligently without manual intervention. Local data including acquired biomedical parameters this time, user identification, and other related limited information will be delivered to server for further analysis. Since the server in upstream is equipped with comprehensive data base (DB) storing all user clients' information and abundant disease knowledge, it is able to recognize the rule configuration in user client device. Grounded on this, the server will perform analysis on the received data to obtain detailed highly precise diagnostic results as well as the related rules for diagnosing such a CVD. Finally, the diagnostic results and related useful rules will be packaged and transmitted to user device for local update. Note that, rather than sending back all the useful rules, only the local absent or outdated rules for certain disease are dug out. With such a delta update scheme, it minimizes the necessary dataflow between up and down streams as well as contributes to the fluent execution of local update without the need of re-install.

2) Master-slave knowledge base scheme

During the KB update process, several unexpected situations may occur, such as sudden power off, system failure, system exit or etc., which will not only influence the success of update but also damage the original KB file and even the overall system. Tackling this, a master-slave KB update scheme is pioneered in this paper. As depicted in Fig. 3, on receiving update package from upstream, the local embedded-link device will create a new blank slave KB. Instead of directly overwriting the master KB, the local device will analyze the received update package and original master KB file and write the up-to-date rules into slave KB file. Before completion of update process, the master KB is employed for local diagnosis. Once interruption happens during update, the incomplete slave KB file will be discarded at the beginning of next retrial. After successful update, the slave KB will be adopted as master KB, while the original master KB will be archived within the local device for backup. Note that the backed-up KB is to roll back to last version if any abnormality is detected after update or user would like to withdraw the update. All in all, this master-slave update scheme assures safety and reliability of the update process in UUS as well as robustness of the overall system.

C. Intelligent Diagnosis Program

Based on the constructed KB, a CVD diagnosis system is designed and constructed. With an intelligent inference engine, the system is able to perform preliminary CVD diagnosis on embedded-link local devices.

First, all the rules in local KB are loaded into inference engine, and then the engine will judge conditions of those rules according to acquired biomedical parameters. If certain rule is satisfied, the corresponding disease index will be recorded as potential disease. According to the inference results, user's health status and possible diseases results as well as the corresponding pathological warning messages will be indicated. The warning messages actually are recommendations for users on timely actions, which may include one or multiple of the following items: 1) improve practices in daily life and diets; 2) pay attention to particular biomedical parameters, non-measurable symptoms or feelings (like dizziness or hard to breath); 3) trigger KB update for further precise analysis; 4) seek for medical treatment immediately. Fig. 4 shows an example of diagnostic result and warning message is showed on mobile device for a patient with hypertension. As suggested in the warning message, the parameter of blood pressure should be monitored from time to time. Besides, the hypertension extension package is also listed in this interface for customized update. In conclusion, the intelligent diagnostic program provides comprehensive health status information to help users monitor health status and take appropriate actions accordingly.

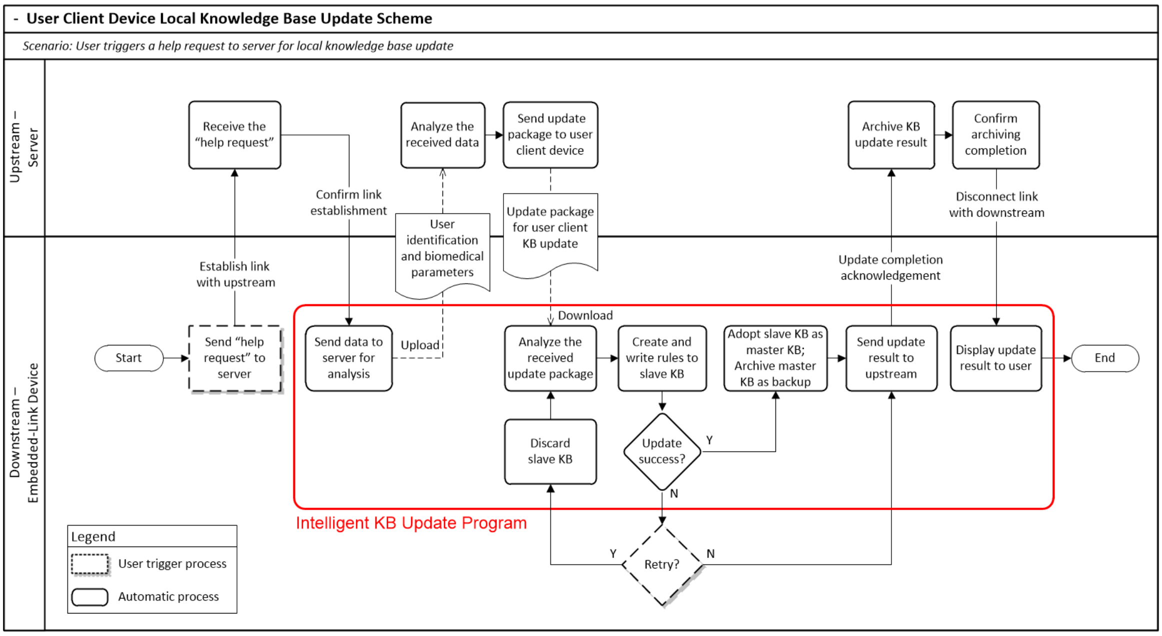

Fig. 3. Flowchart of local KB update process in user client device.

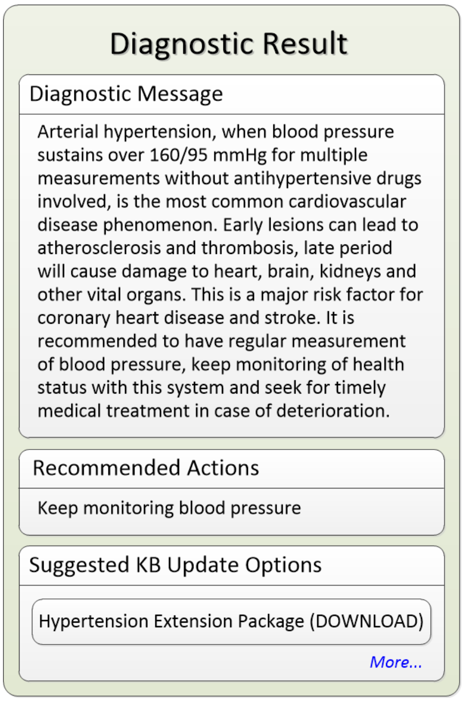

Fig. 4. A diagnostic result of hypertension shown on mobile device.

III. Conclusion

In this paper, a novel intelligent KMS is proposed and developed for distributed e-home healthcare applications via Java language. With a dedicated KB framework and customized rules configuration, the resource-limited user mobile devices are able to store adequate personalized knowledge rules. An intelligent KB delta update scheme is introduced to perform absent rules update individually and automatically with minimum dataflow. Furthermore, the pioneered master-slave KB approach ensures the reliability and safety of the whole system. Finally, an intelligent diagnosis system with the designed KB is constructed. The future work will be the system improvement in terms of multi-tasking and prioritizing of user requests, simplifying knowledge rules representation and fastering the diagnostic procedure with higher diagnostic accuracy.

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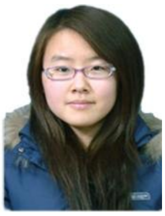

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