Health Condition Alarm System

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Abstract. A Health Condition Alarm System has been developed to provide practitioners an update on their patients' conditions in real-time. This paper focuses on how researchers and doctors can use the system to create vital sign ranges and alarm levels as well as to see the alarm alerts. The system is webbased and open-access, and the research team would like to collaborate with practitioners, hospitals, laboratories, and medical professionals to expand the system's application domains. The research team has leveraged two quality control methods, X-Chart and Westgard Multi-Rule, to decide the alarm level of a patient's health condition and the alarm timing. Four alarm levels (i.e., normal, subnormal, cautious, and alert) can then be decided by the mean values and standard deviations of the patient examination data.

Keywords: Healthcare, Data Mining, Westgard Multi-Rule Quality Management, X-Chart, Levey-Jennings Control Chart.

1 Introduction

The research team intended to design an ideal tele-healthcare system for elderly healthcare patients [1-3]. With this system's help, doctors can obtain a clear picture of the health conditions of elderly patients without the patients being required to visit the hospital frequently. The research team used X-chart and Westgard multi-rule quality management [4-5] to first analyze patients' physical examination data and then categorize their health conditions into different alarm levels. These alarm levels remind medical professionals when to take action and also reduce the chance of false alarm being generated [6]. The algorithm was implemented as a built-in module of the tele-healthcare system; outside the tele-healthcare system, the module cannot be accessed. Additionally, the vital signs, vital sign ranges, and alarm rules are fixed and cannot be altered without recompiling the entire system.

Because the criteria of health condition measurements vary among different countries, regions, and healthcare professionals, the research team implemented a more sophisticated and flexible open-access health condition alarm system on the Internet. The system itself is a complete solution that health practitioners working in clinics can use it to enter patient's examination data and their observations, diagnosis, and suggestions. Furthermore, the system can also be extended to support complicated lab data

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results feeds and corresponding rules establishment, for instances, the normal body temperature ranges from 97.6 F to 99.6 F; the adult fever temperature ranges from 100 F (oral temperature) to 101 F (rectal or ear temperature); and, the child fever temperature ranges from 100 F (oral temperature) to 100.4 F (rectal or ear temperature).

This paper is organized into three main sections. Section 2 explains the fundamental concepts and designs of the health condition alarm mechanism. (For more details on this topic, readers can study the research team's previously published work [6].) Section 3 discusses introduces how health practitioners can use the system. Last, section 4 demonstrates the flexibility of the system and explains how medical professionals can set up and add health conditions, lab data units and ranges, as well as rubric information.

2 Concepts of the Health Condition Alarm Mechanism

It is important to provide healthcare practitioners with an update or notification of a patient's health condition (assessed and diagnosed through examination data, e.g., vital signs and lab results). This research uses two quality control methods, X-Chart and Westgard Multi-Rule, to decide the specific alarm level that corresponds to a patient's health condition and the alarm timing. An alarm has four levels: normal (A), subnormal (B), cautious (C), and alert (D). Alarm levels are decided by the X-Chart method based on the mean values (M) and standard deviations (SD) of the patient examination data [7].

After acquiring the mean value and standard deviation of the examination data, the top limit is set as M + 3SD and the bottom limit is set as M - 3SD. The data in the range between M + 3SD and M - 3SD is called the action limit, as Figure 1 shows. If the patient's examination data goes beyond the action limit, then the Westgard Multi-Rule method may be applied to reassess the patient's examination data. Data that falls into the range between M + 2SD and M - 2SD will be seen as an "Alert."

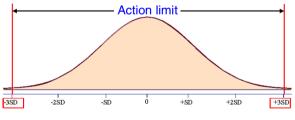


Fig. 1. Action Limit

The range between M + 2SD and M - 2SD is the warning limit (Figure 2). If the patient's examination data goes beyond the warning limit, then practitioners may need to take appropriate actions for the patient. The warning limit includes three alarms levels: normal (A), subnormal (B), and cautious (C). The range between M + 1.5SD and M + 2SD or between M - 1.5SD and M - 2SD is "cautious"; the range between M + SD and M + 1.5SD or between M - SD and M - 1.5SD is "subnormal"; and the range between M + SD and M - SD is "normal."

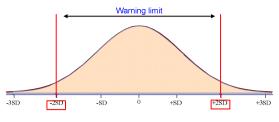


Fig. 2. Warning Limit

3 The Health Condition Alarm System for Practitioners

The research team is aiming to make the health condition alarm mechanism available to all healthcare practitioners, as well as hospitals, healthcare facilities, and medical service providers; hence, a web-based open-access solution is the most expedient option. We would also like to provide healthcare practitioners and facilities a complete and flexible health condition alarm solution; therefore, we design and implement all functions that doctors and administrative professionals require. In this paper, we will focus on the use cases of doctors and administrative professionals who have used the system on a trial basis.

As shown by Figure 3, the Health Condition Alarm System is comprised of a number of independent components. These components were individually developed in Java; as the project progressed, the components were integrated with one another when appropriate. The system is running on the Linux server (i.e., Debian) including all other GNU General Public License servers and services. Since one of our objectives is to offer doctors and administrative professionals a complete, free, open-access online solution, the system has two pre-determined user roles: doctor and administrator.

AP NO	DTE TRA	ACKING & ANALYSI	3 SYSTEM	1			Logo
S	DAP NO	TESE	ARCH	ADMIN	IISTRATION	L	
					Clear	Submit	Alarm Panel
Con	sultation	Patient Vital Signs	SOAP	Patient Allerg	jies Remarl	ks	Hypertension Alarm
	it Date ctor	04/23/2013 Dr Chang Maiga		Name MRC			Level Risk
Ro	om	1	~	HCN Blood Grou			- Obesity Alarm Level
Pat	ient Id			Smoking His			Risk
	[Retreive Patien	t				Heart Condition Alarm
							Level Risk

Fig. 3. Main screen of the system

When a practitioner signs in to the system, there will be three main functions or tasks the practitioner can access and perform, shown in Figure 3. However, before the practitioner can see the heads-up notification of a patient's health condition, he or she must access the patient's data by entering the patient's ID and clicking the "Retrieve Patient" button.

The practitioner can enter examination data as well as his or her diagnosis, comments, and suggestions for the patient (see Figure 4). Once the data and accompanying notes have been entered into the system, the health condition alarm mechanism will be activated. For example, a practitioner can see a subnormal notice with the risk of getting into pre-hypertension stage on the alarm panel at the right hand side of the screen (Figure 5). A practitioner can also choose whether or not to see the alarms whose levels are not over a certain level.

SOAP NO	TE SE/	ARCH	ADMINIS	TRATION		
				Clear	Submit	Alarm Panel
Consultation	Patient Vital Signs	SOAP	Patient Allergies	Remarks		Hypertension Alarm
Visit Date	04/23/2013		Name	John Smith		Level Risk
Doctor	Dr Chang Maiga		MRC	MRC1		
Room	1	~	HCN	HCN1		Level
Patient Id	P1		Blood Group Smoking Histo	A ry 🗖		Risk
	Retreive Patient					Heart Condition Alarm
						Level
						Level

Fig. 4. Practitioners can enter examination data, analysis results and comments after retrieving the patient's information

If the practitioner needs to, he or she can also search the historical data for the patient. When this is done, the health condition alarm mechanism is automatically applied to the time period of the historical data; the practitioner can then see notifications regarding the patient's health condition (Figure 6). In this simulation case, the practitioner can see two subnormal notices relating to hypertension and obesity problems the patient has.

4 Health Condition Alarm System for Administrative Users

Since the criteria for measuring and evaluating a patient's health condition(s) through the analysis of examination data and lab results differ among health facilities around the world, the system provides administrative professionals with functions to: (1) add labels (i.e., vital signs in the system), units, and ranges for lab results; (2) add health

			Clear Submit	Alarm Panel
Consultation	Patient Vital Signs SC	AP Patient Allergies	Remarks	Hypertension Alarm
Visit Date 2	012/10/25	Name	John Smith	Level Subnormal Risk Pre Hypertension
Doctor D	r Mark Jenson	MRC	MRC1	- Obesity Alarm
Room 1	×	HCN	HCN1	
		Blood Group	А	Level Normal Alaum Panel
Patient Id P1	1	Smoking Histor	у 🗖	Risk Normal
				Heart Condition Alarm
				Level Normal
				Risk Normal
				L

Fig. 5. Practitioners can see the alarm(s) once new data has been entered.

INACIAL TRACT	KING & ANALYSIS SY	STEM		Logout
SOAP NOTE	SEARC		TRATION	
Search SOAP NOT	E Search Results			Patient Name John Smith
Display 10 💌	records	Search:		Gender: M Age: 59
Date ¢	BP (mm Hg) ≎	Pulse(bpm) ≎	BMI(kg/m^) ≎	Alarm Panel
25/10/2012	120/79	100	23 28	Hypertension Alarm
26/10/2012 26/10/2012	110/78 90/68	100	28	Level Subnormal
Showing 1 to 3 of 3		100	00	Risk Pre Hypertension
				- Obesity Alarm
				Level Subnormal
				Risk Overweight
				Heart Condition Alarm

Fig. 6. Practitioners can search the historical data of his or her patient and the health condition alarm mechanism is applied to the historical data automatically

conditions and manage the associations between the health conditions and vital signs; and (3) establish the connections among alarms and health condition risks.

If administrative professionals have any lab results which the current system does not support, they can use the Vital Sign Management function (shown in Figure 7) to add new vital sign names and their units. Once vital signs have been added, practitioners can enter the data or information for the patient(s). Because the alarm mechanism uses mean values and standard deviations to test the examination data, the administrative professionals need to add ranges for the vital signs (see Figure 8).

SOAP N	OTE SEAR	CH ADMINIS	TRATION		
Doctors Patio	ents Researcher				
Vital Sign	/ital Sign Ranges Health	Conditions Health Condit	ion/Vital Sign Association	Simple Rules	
Display 10	recordsSearch:		Id		
Id	Name	Unit	Name		
6	pulse	bpm			
5	bmi	kg/m ^a	Unit		
4	Height	cm			
3	Weight	kg			
	bp_Hg	mmHg	Clear	Submit	
1	bp_mm	mmHg			
Showing 1 to i	5 of 6 entries	00			
Shoung 1 to					

Fig. 7. Administrative professionals can add new vital sign names for lab results

AP NOTE T	RACKING & ANA	LYSIS SY	STEM					Logout
SOAP	NOTE	SEAR	сн	ADMINISTR	ATION			
octors Pa	tients Researche	er						
Vital Sign	Vital Sign Ranges	Health	Conditions H	ealth Condition\	vital Sign Association	Simple Rule	5	
Minimum	0 💌 recordsSe Maximum	Risk	Risk Desc	ription	ld Vital Sig	1	Select	~
¢ pulse	¢ 183	¢ 9999	♦ Alert		Lower Ra	nge(Min/Max)		
pulse	0	39	Alert					
pulse	142	182	Cautions		Upper Ra	ige(Min/Max)		
pulse	40	49	Cautions					
pulse	101	141	Subnormal		Risk Des	vintion		
pulse	50	59	Subnormal		NISK Des	anihanan.		
pulse	60	100	Normal		Risk		Select	~
	35	99999	Alert					-
bmi	0	14.4	Alert					
bmi		34.99	Cautions					Submit
bmi bmi	0 10 of 28 entries			00			Clear	

Fig. 8. Administrative professionals can add alarm ranges for particular vital signs

The assessment of a health condition can only be made based on one or more vital signs. For example, the practitioner may need to consider both blood pressure and pulse to tell if a patient is at risk for hypertension problems. In this system, the administrative professionals can first add the health condition(s) for the newly added vital signs (shown in Figure 9). They can then relate the vital signs (i.e., lab results) with the health condition(s), as Figure 10 shows.

SOAP NOTE TRACKING & ANA	LYSIS SYSTEM			Logout
SOAP NOTE	SEARCH	ADMINISTRATION		
Doctors Patients Researche	er			
Vital Sign Vital Sign Ranges	Health Conditions	Health ConditionWital Sign Association	Simple Rules	
	Health Condition	Hypertension		
	Vital Signs	Selected Vital Signs		
	bmi bp_Hg bp_mm Height pulse Weight	bp_mm bp_Hg bmi		
	weight	•		

Fig. 9. Administrative professionals can add health condition(s) for particular vital signs

votors Putients Researcher Vital Sign Vital Sign Aanges Mealth Conditions Mealth Condition/Vital Sign Association Simple Rules Display 10 2 recordsSearch: Id Id Name Name	SOAP NOTE S	SEARCH ADMI	NISTRATION		
Display 10 2 recordsSearch: Id	Patients Researcher				
Display 10 v recordsSearch:	Sign Vital Sign Ranges	Health Conditions Health C	ondition\Vital Sign Assoc	iation Simple Rules	
Display 10 v recordsSearch:					
	ay 10 💌 recordsSear	ch:	Id		
	ld O	Name	Name		
3 Obesity Clear Submit				Citere Cuterit	
2 Heart Condition		on		Clear Submit	
1 Hypertension					
Showing 1 to 3 of 3 entries	ving 1 to 3 of 3 entries		00		

Fig. 10. Administrative professionals can associate health condition(s) with vital signs

The third function administrative professionals can perform deals with creating a rubric or set of rules which link both the alarm levels of vital signs and the risks of getting health problems together. For instance, a patient may be in one of four risk categories of having hypertension: normal, pre-hypertension, hypertension stage 1, and hypertension stage 2. Administrators thus need the Rules function (shown in Figure 11) to create the rubric, so that healthcare practitioners can see the appropriate alarm-relevant notifications in the alarm panel.

		& ANALYSIS	SYSTEM				Logout
SOA	AP NOTE	SEA	RCH ADMIN	ISTRATION			
Doctors	Patients R	lesearcher					
Vital Sign	Vital Sign F	Ranges Heal	Ith Conditions Health Con	ditionWital Sign Asso	siation Simple Ru	ules	
Hea	rt Condition	~					
				Health Condition	Heart Condition	~	
				Health Condition			
Display	10 💌 r	ecords			Heart Condition		
Display	10 💌 r						
ld	pulse	ecords Search: Risk	Desc		pulse		
ld	pulse	ecords Search: Risk	0		pulse		
ld 4	pulse ≎ Alert	ecords Search: Risk ¢ Alert	Heart Condition Stage II	Vital Sign	pulse		
ld • 3	pulse ≎ Alert Cautions	ecords Search: Risk Alert Cautions	Heart Condition Stage I Heart Condition Stage I	Vital Sign	pulse		
ld 4	pulse ≎ Alert Cautions Subnormal	ecords Search: Risk ≎ Alert Cautions Subnormal	Heart Condition Stage II Heart Condition Stage I Pre Heart Condition	Vital Sign	pulse Generate R	₩	
ld 4 3 2 1	pulse ≎ Alert Cautions Subnormal Normal	ecords Search: Risk Alert Cautions Subnormal Normal	Heart Condition Stage II Heart Condition Stage I Pre Heart Condition Normal	Vital Sign	pulse		
ld 4 3 2 1	pulse ≎ Alert Cautions Subnormal	ecords Search: Risk Alert Cautions Subnormal Normal	Heart Condition Stage II Heart Condition Stage I Pre Heart Condition	Vital Sign	pulse Generate R	₩	

Fig. 11. Administrative professionals can create rules for specific health problem

5 Conclusion

The Health Condition Alarm System is a web-based open-access system for health practitioners, healthcare organizations and facilities such as hospitals and clinics, and medical professionals. The system is self-sustainable and has all the functions that practitioners and administrative professionals need: The system not only allows administrative professionals to add new lab results, health conditions and risks, but also allows them to customize (depending on country and/or different facility) using their own criteria of measuring a patient's health condition(s) in regards to reading and analysing lab results. Individual patients can also use the system to both monitor their health condition(s) and receive alarms or notifications about the likelihood and risks of having health problems. All that is required to use the system is a record of their examinations data and lab results.

The research team would like to collaborate with healthcare practitioners, clinics, hospitals, organizations, and information service providers (i.e., industry partners) to test the usability of this system as well as to get user perceptions and comments about the system to make further improvements in the future. The research team also hopes

to have the opportunity to expand the database of vital signs and health conditions, so that the system can be more beneficial and effective for users.

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