INTELLIGENT SYSTEMS TO SUPPORTING PREMATURE BABIES HEALTHCARE WITH MOBILE DEVICES

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Abstract

Recent studies show that premature babies who need a supervision period can shorten this time if they are in a familiar environment. However, complications might arise at any time. This work proposes an approach to monitor babies at home. In this approach, baby sensors send data to a mobile device implementing an intelligent system that provides recommendations and supports the parents in the baby care. The system is composed by a rule-based system and a case-based system, using the knowledge provided by physicians and historical data. In the last step the assessments derived from the application are always contrasted by the medical staff. An illustrative example argues for the need to use systems able to personalize the physician's knowledge, rather than using simple rules that they cannot generalize it.

Keywords

mHeath, Mobile Computing, Healthcare, Intelligent Systems, Case Based Reasoning, Medical Decision Support System

Introduction

Every year around 500,000 kids are born prematurely. These babies need special medical attention in the neonatal intensive care unit (NICU). They need hospital supervision until their systems and organs can function with no external assistance. Recent studies show that during part of this time the baby needs only supervision rather than medical treatment and that this time is shorter if spent in a familiar and loving environment. However, complications might arise at any time and the vital signs of the baby should be closely monitored. To monitor babies at home, mobile devices offer an invaluable service. Our work is related to developing an application for home care of premature babies thanks to mobile devices. The work is framed in the MoSHCA project.

MoSHCA [1] is a mHealth project designed to improve the patient-doctor interaction and control of diseases. The number of people with chronic or long treatment diseases is growing worldwide. Self-management of such diseases is crucial in the prevention of serious and costly complications. MoSHCA provides intelligent, user-friendly, secure, medical and well-being decision-making embedded software, utilizing medical sensors that synchronize with the mobile phone, and this in turn with medical information systems. MoSHCA enables the home care of several patients that otherwise should extend their hospital stay. The authors of this paper are two of the partners of the MoSHCA project (IdIBGI and the eXiT research group of the University of Girona) which focus on the case use of the system for home care of premature babies.

There are some applications available off-the-shelf ([2],[3]), most of them designed to collect information at home that is processed later on by physicians. The monitoring that they are currently performing consists on filtering out the information entered by the cares manually, and locally, at the mobile device, they perform a simple filtering of the values entered according to some given allowed ranges. From our understanding, mobile devices has much more capacity, and are currently able to host most sophisticated applications. Particularly, we focus on including Artificial Intelligence based decision support techniques to make mobile applications smart.

Our goal is to provide mobile devices to premature babies' cares with an intelligent reasoning module that provides recommendations and supports them in the baby care. For that purpose, we consider a hybrid approach based on a rule-based system (RBS) and a case-based reasoning (CBR) system. While with the former we can achieve some general recommendation based on a priori knowledge provided by physicians, with the later we can conduct a personalized supervision of babies. Nevertheless, CBR requires from some historical data that constraints its use from the beginning. So both modules complement each other. In the approach we follow all the information gathered and entered in the application as well as the recommendation performed by the intelligent components are sent back and processed in a host and its made available to the medical staff, which at the ends is the ultimate responsible of the baby health.

Related work

Currently there are some cases of applications for mobile using CBR, but mainly on tourism applications. In the healthcare domain, CBR on mobile applications has also been used in the field of smoking cessation [4]. The authors state that mobile based messaging systems have already experienced acceptability when backed by the motivation to undertake certain behavior changes, according to the results of several experiments. CBR enables in this case, the personalization of messages. Other health applications on mobile phone lacks of intelligent components, as we are developing.

Methods

To monitor the baby state, we follow a four basic step framework: perception, reasoning, actuation and learning. This four-step approach corresponds to the main components of an intelligent system itself, which can be implemented by either a RBS and a CBR system, for example.

The 4 step approach (PRAL)

First, **perception** is related to gather baby's data. Values on variables described in Table 1 are collected using the corresponding sensors. Sensors used include baby pulse-oxymeter and a baby scale, which provide the information in a wireless basis (for details on the architecture and interoperability issues, see [1]).

On the other hand, some other derived variables are also defined, as the weight increment which is set using weight and date of measurement. The weight itself doesn't give as important information from a medical point of view as weight increment does.

Second, **reasoning** about the data to assess baby's state. For that purpose, a rule-based system and a case-based system are proposed. These systems are outlined in next subsections.

Tab. 1: Input variables

Date and hour of measurement: date and time of day when the baby is assessed.
General aspect: normal colour and breathing normally.
Weight: weight of undressed infant in gr.
Heart rate: heart beats per minute.
Respiratory rate: respirations per minute.
Haemoglobin saturation: percentage of oxygen saturated haemoglobin.
Axillary temperature: skin temperature taken in the axilla in Celsius degrees.
Bilirubin: concentration of total bilirubin, as estimated by a transcutaneous detector.
Feedings a day: number of feeds per day.
Daily stools: YES, or NO, depending on whether the baby passes daily stools or not.
Weekly stools: Number of stools in a week, in case they are not passed on a daily basis.
Sleeping: whenever the baby sleep mostly during the day, at night, or at any time during the day and night.
Taking vitamins supplements: whether the baby receives iron supplements or not.
Taking iron: whether the baby receives other medications or not.
Taking other medication.
Other aspects: hygiene, ambient temperature, intercurrent illnesses.

Third, in the **actuation** step communicative acts are performed to respond to the baby's state. Three possible assessments are given:

- Normal. The baby progress is satisfactory.
- Warning. The physician, after reviewing the baby's information establishes communication with the baby's parents via the MoSHCA platform.
- Alert. The system lets out an alarm. Then, parents should contact the hospital and get new instructions. Doctor examines the data.

And fourth, the system **learns** from the outcomes of the previous steps. Physicians provide some feedback that could confirm or deny the recommendation performed by the reasoning components. When the reasoning component has learning capabilities, as CBR includes, the feedback is used to improve future recommendations.

Rule-based system

The starting point of RBS is a set of simple rules provided by physicians, regarding general knowledge about premature baby monitoring. These rules are defined taking into account the normal range of values of a subset of baby's variables (see Table 2). If the value of a given variable is out of the normal range; the rule is fired.

Tab. 2: Normal ranges for variables used in the rule-based system (lb: lower bound; up: upper bound).

Rule	Variable (rule)	lb	ub	Units
1	Weight increment	25	-	g/day
2	Heart rate	110	175	Beats per minute
3	Respiratory rate	35	55	Breaths per minute
4	Haemoglobin	94	-	%
5	Temperature	35.5	37.5	ºC
6	Bilirubin	-	15	mg/dL

Case-based system

Alternatively to the previous method, CBR can provide a personalized recommendation. CBR is a methodology for developing knowledge-based systems that attempts to solve a given problem within a specific domain by adapting established solutions to similar problems ([5],[6]). The CBR process is divided in four main steps known as the four Rs, shown in figure 1. The input of the cycle is a new case of a problem to be solved, and a case base with instances of the same problem that have already been solved. First of all, the most similar cases are retrieved of the case base. Then, the solution of these past cases is reused to solve the new case. After that, this solution can be revised and finally retained in the case base for future usages.

What we want to obtain from the CBR system is an output saying whether there is a risk for baby's health or not. In so doing, the case consists of two parts: problem or baby measurements (variables of Table 1), and the solution or baby state assessment.

Medical criteria says that the same values of measurements can take different meanings for two different babies, since the normality ranges of values can be different for each baby, depending on their basal information. The basal information is the measurements taken when the baby lefts the hospital and moves home. Each baby has a different departing point, as weight, breath rate, etc. For this reason, developing a single CBR system built upon the measurements of all the babies has no value, and would collapse to the general rule approach. Instead, we develop a personalized CBR system for each baby.

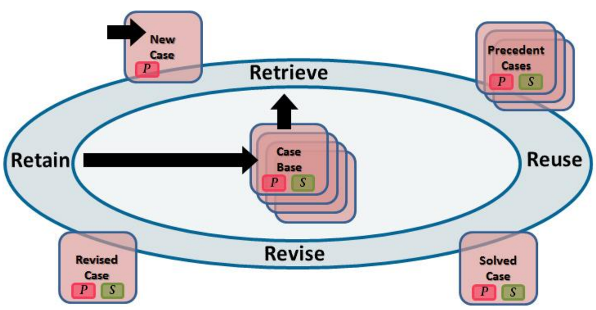

Fig. 1: Four-step process (4R) of Case-Based Reasoning (based on (Aamodt & Plaza, 1994))

Tab. 3: Example of gathered values for two different babies. It is shown their basal values and one of the monitoring cases.

	Baby 1		Baby 2	
	Basal	Case 3	Basal	Case 3
General aspect	Good	Good	Good	Good
Weight (gr)	1830	1830	1620	1730
Daily weigth increment (gr)		16		16,66
Heart rate (bpm)	135	137	125	130
Breath rate (rpm)	37	40	37	32
Haemoglobin saturation (%)	99	97	99	98
Axillary temperature (ºC)	36,8	36,1	36,5	36,2
Bilirubin (mg/dL)	2	1,7	12	11
Feedings a day	6	6	8	8
Daily stools (weekly stools)	NO (2)	NO (1)	Yes	Yes
Sleeping	Day	Same	Same	Night
Medication				
Vitamines	Yes	Yes	Yes	Yes
Iron	Yes	Yes	Yes	Yes
Other	Yes	Yes	Yes	Yes

Cases study

In this section we analyze how the system will provide recommendation to two different, in-silico babies, with two different basal situations (see Table 3). Due to their differences, the duration of the monitoring differs: baby1 accounts 6 monitoring activities, while baby2 5.

Tables 4 and 5 show the recommendations obtained by the system for baby1 and baby2 respectively. First column indicates the monitoring activity, so they are sequential; the activity labelled as 0 corresponds to the basal values. Second column is the assessment provided by the RBS, while the third column the one provided by the CBR system. Finally, the last column shows the feedback provided by paediatrics. Besides, the RBS column also shows the triggered rule according to Table 2. On the other hand, note that CBR only made decisions beginning from case 3. The cases 0, 1, and 2 are used to set up the case-base considering the solution of these cases the physician's feedback.

Thus, the obtained assessments are compared with physician's evaluation. As may be seen in the tables, and without taking into consideration the first three cases, these preliminary results show that rule-based system tends to have a higher false positive, and case-based reasoning tends to cause a lower rate, but still high regarding the recommendation made by the clinical staff.

In the case of the RBS, it can be appreciated that false alarms arise from values outside the weight increment rate (rule 1) and the respiratory rate (rule 3).

Tab. 4: State assessment of baby1 provided by the RBS, the CBR system and physicians.

Case #	RBS	CBR	Physicians
0	Normal	-	Normal
1	Warning (1)	-	Warning
2	Warning (3)	-	Normal
3	Warning (1)	Normal	Normal
4	Warning (3)	Normal	Normal
5	Warning (1)	Normal	Normal
6	Warning (1,3)	Warning	Normal

Regarding weight variations, most cases were not disturbing for physicians that evaluated the patient's status according to the totality of the available variables. And, in the case of respiratory rate, it is not unusual to have respiratory rate readings beyond the normal range for infants, since it is well known that this medical parameter is easily affected when assessed in an infant who is not awake and quiet. Therefore the respiratory rate could generate unnecessary alarms.

Regarding the CBR system, the cause of false alarms could be due to the fact that there are still few cases available for testing, so the initial database of cases cannot be fed at the beginning with information from previous babies. It is important to observe that CBR suffers from the cold start problem, which consist in the fact that the first cases on the case base condition the first recommendation. If cases do not represent appropriately the application solutions (e.g., there are not cases for all the possible outcomes, normal, warning, alert), first recommendations would be wrong, unless the appropriate feedback is provided to the system. For example, case 3 of baby1 and baby2 (Table 3), are very similar to their basal settings, even several variables from both cases are similar, but the outcomes are normal and warning, respectively (see the fourth row of Table 4 and 5). That means that the history on each individual has been taken into account. A possible solution is to set up the case base with historical data of the baby while being at the NICU. Nevertheless, baby1's outcome is improved in regard to the RBS, since the normality ranges in two babies with different basal settings can be different.

Conclusion

There is an increase number of premature babies that, once they achieve some degree of maturity, can be moved at home when they parents can take care of them in a loving environment which most of the times fasten the babies recovery. For this end, a mobile application is provided, which supports parents in the baby care. The application contains an intelligent module that assesses the baby state by reasoning locally, at the mobile device. Our approach is based in 4 steps, and is implemented and compared with two

Tab. 5: State assessment of baby2 provided by the RBS, the CBR system and physicians.

Case #	RBS	CBR	Physicians
0	Normal	-	Normal
1	Warning (1)	-	Warning
2	Normal	-	Normal
3	Warning (1,3)	Warning	Normal
4	Normal	Warning	Normal
5	Warning (3)	Normal	Normal

different technologies: RBS and CBR. A case study is analyzed on two premature babies with different basal situations. These results argue for the need to use systems able to personalize the physician's knowledge, rather than using simple rules that they cannot generalize it.

Our future work involves further experimentation including the testing in a real environment within the MoSHCA platform. In that doing, we need to face the problem on improving the cold start problem for CBR.

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