A GENERIC APPROACH TO A MOBILE MONITORING SYSTEM

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Abstract

This article demonstrates a generic approach to a mobile monitoring system for automatic early detection of a progressive course of several diseases. The monitoring by the system can help ambulant patients to avoid some complications. Used as the mobile component, a specially programmed smart phone initiates self-tests peculiar to some disease: the tasks downloaded from a central server request to perform the tests and retrieve their results. The mobile component uploads the test results back onto the server. Based on the results, the system automatically selects the patients with a progressive course of their diseases and alerts responsible physicians.

Key Words
patient monitoring, telemedicine, health care information systems, alerting of physicians

1. Introduction

Early detection of a progressive course of certain chronic diseases is very important to avoid complications. Currently, an examination of an ambulant patient state is performed periodically by visiting a physician. The method lacks promptness and flexibility: patients with the favourable course of disease are examined just as often as patients with a progressive course. Thus, the schedule of the patient examination can be optimised.

This article discusses a generic approach to a monitoring system using mobile components (specially programmed smart phones) for automatic detection of a progressive course of several diseases. The existing Mobile Memory Aid System MEMOS\(^1\) [1, 2] used to support patients with deficits in the prospective memory can also be applied to monitor other groups of patients.

Many patients themselves examine their state by some diseases periodically, or estimate it using special scales, for instance diabetic patients measure glycemia, patients with hypertension measure blood pressure, the obese patients measure their weight and patients with pain can estimate it using the special scales.

The idea is to build the generic mobile monitoring system that initiates diverse patient self-tests and collects their results on the central server providing physician access to these results per Internet. Since the number of treated patients can be very large, the system detects the patients with a progressive course of a disease automatically and alerts the responsible physicians thereby.

Each patient is furnished with a standard mobile device programmed to execute tasks written in a standard format. Special tasks can be developed for each disease, which initiate self-tests peculiar to the disease and request their results for upload to the central server. The interactions between physicians, patients and monitoring system are schematically shown on Fig. 1.

Fig. 1. Interactions between physicians, patients and monitoring system.

Based on the results of the tests and notifications generated by the system, physicians can optimise the plan of patient examination. Thereby, a progressive course of a disease of some patients can be detected earlier and these patients can be examined first, what helps to prevent complications.

Another benefit of the system is that it applies standard widespread components such as smart phones, uses the results of standard self-tests and does not need special sensors and equipment. The system requires the minimal cooperation of the patients by executing task only. Application of diverse tasks allows using the system

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as a platform to monitor patients with several diseases, which makes the system universal. It can also reduce the monitoring costs for equipment and service staff.

2. Monitoring

First, we define the target group of patients. It makes sense to use the system for ambulant patients with chronic diseases, which may not be continuously monitored by physicians. The main criterion is that such patients should make the simple tests of their health themselves and report the results of these tests to the physicians periodically for correction of their treatment. They can live an active life, i.e. they are not confined to bed or house. In particular, such groups can be diabetic and obese patients, pain patients, patients with hypertension, etc.

Fig. 2. Simplified task to inquire the results of a blood test for diabetic patient: a card area drawn by a solid line is visible to the patient; a card area drawn by a dashed line contains service information for the browser.

The special tasks can be developed for each group of patients. Such tasks are questionnaires to monitor the state of a patient. Each task is represented as a graph, whose nodes are cards and edges being event handlers. Each card represents a single interaction with the patient. It specifies a request of particular information from the patient and offers some reactions for him. Each offered reaction is specified by the event handler referring to some card. The navigation through the graph proceeds depending on the patient’s choice of a reaction during task execution on a mobile device. Each task specifies also some temporal parameters, which are important to its execution, such as start time and expiration time.

Fig. 2. demonstrates a simplified task to inquire the results of a blood test for diabetic patients. The task detects whether a patient has hypoglycemia or hyperglycemia. The value of glycemia can be defined more precisely by the application of a more complex task containing more cards.

![Table of Statistical Rules](image1)

<table>
<thead>
<tr>
<th>ID</th>
<th>Card List Base</th>
<th>Alarm 1</th>
<th>Alarm 2</th>
<th>Alarm Message 1</th>
<th>Alarm Message 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>r0</td>
<td>1/3</td>
<td>8</td>
<td>5</td>
<td>&quot;3*Hypoglycemia in 8 tests&quot;</td>
<td></td>
</tr>
<tr>
<td>r1</td>
<td>4/5</td>
<td>9</td>
<td>5</td>
<td>&quot;4*Hyperglycemia in 9 tests&quot;</td>
<td></td>
</tr>
<tr>
<td>r2</td>
<td>1/2, 4/3</td>
<td>10</td>
<td>5</td>
<td>&quot;Instable Glycemia&quot;</td>
<td></td>
</tr>
</tbody>
</table>

![Parameter Table](image2)

<table>
<thead>
<tr>
<th>ID</th>
<th>Type</th>
<th>Default</th>
<th>Setting Prompt</th>
<th>Value</th>
<th>Flag</th>
</tr>
</thead>
<tbody>
<tr>
<td>p0</td>
<td>string</td>
<td>auto</td>
<td>Start time of test</td>
<td></td>
<td></td>
</tr>
<tr>
<td>p1</td>
<td>date</td>
<td>manual</td>
<td>Task expiration time</td>
<td>Upper glycemia bound</td>
<td></td>
</tr>
<tr>
<td>p2</td>
<td>date</td>
<td>manual</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>p3</td>
<td>string</td>
<td>4 mmol/l</td>
<td></td>
<td>Lower glycemia bound</td>
<td></td>
</tr>
<tr>
<td>p4</td>
<td>string</td>
<td>7 mmol/l</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

![Control Info](image3)

Task ID: 56789
Start time: 10:00
Expire time: 12:00

Card 0: normal
History: “Start test”
Start test!
Value of Glycemia is lower as 4 mmol/l
Yes
No

Card 1: critical
History: “Hypoglycemia”
Take glucose immediately!

Card 2: normal
Value of Glycemia is higher as 8 mmol/l
Yes
No

Card 3: end
History: “Normal”
Value of Glycemia is normal

Card 4: critical
History: “Hyperglycemia”
Inject insulin immediately

Fig. 3. Simplified template for tasks to inquire results of the blood test for diabetic patients.

Each card can specify a record, which is written into the log file of mobile device, if patient navigates to this card. Based on the log information transmitted to the server, physicians can determine the value of measured parameters. Every card may also be marked as critical. If patient reaches such card during task execution, his physicians can be alerted immediately. For instance, cards 1 and 4 on Fig. 2.

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In general, each disease suitable for monitoring should be characterised with some lower bound for each measured parameter or with some upper bound or both. Such a general character of the diseases allows the general approach to task construction and statistic handling of the results. The number of reached critical cards can be counted and patient's physicians can be alerted automatically, if the number exceeds a predefined limit within some interval.

On the other hand, such bounds can be also chosen for each patient independently. Furthermore, designing every new task from scratch is a very time consuming and fault-prone process. Therefore, the system should provide a simple and quick way for starting of personally adjusted tasks. We apply templates [3] for it. Thereby, application of the templates provides the generic character of the proposed system.

The template is a prefabricated parameterised task containing a table of parameter descriptions, whose values have to be requested by the physician at the moment of task starting, or have to be set automatically by the system. Each parameter description specifies i.a. a parameter identifier, default value for a parameter, a flag for setting type (auto or manual), the parameter type and a prompt for the physician explaining the meaning of the parameter.

The templates are stored as XML based documents on the server side. Only new templates need to be developed to use the mobile memory aid system to monitor other groups of patients.

Each template is also supplemented with a table of statistical rules describing directives to detect a progressive course of a disease. Such a rule specifies: (1) which critical cards and how often they should be reached for an alert, (2) a number of tests and (3) an alarm type and message that should be sent to physicians. Individual rules can be specified for each patient and each template for the replacement of default directives: if the system does not find individual rules, it applies the default directives.

Fig. 3. shows a corresponding simplified task template to inquire the results of a blood test for diabetic patients. The lower and upper bounds in this template are individually adjustable: in the template, their values are substituted with placeholders, which refer to the parameter descriptions in the parameter table. The statistical module specifies three kinds of alarms:

1. For hypoglycemia, if card 1 is reached 3 times within the last 8 tests.
2. For hyperglycemia, if card 4 is reached 5 times within the last 9 tests.
3. For instable glycemia, if card 1 is reached 2 times and card 4 is reached 3 times within the last 10 tests.

Physicians use the prepared templates for task setting. To set a task, they choose the suitable template and fill the presented parameter table to initialise the parameters. Using time parameters in a task description allows the creation of a proper schedule for the tests. The mobile device not only collects and transmits the test results; it also remains to make tests at a scheduled time.

Tasks written in XML based format [1] are downloaded by the mobile device shortly before their start time. A special developed browser on the mobile device handles the time issues of task description. It alerts the patient at the start time and shows the first card of the task (e.g., Fig. 2. Card 0.). The patient performs the tests and navigates through the tasks according to previous test results and offered reactions.
As mentioned above, the mobile device registers the patient reactions and periodically uploads the log file to the server. Fig. 4. demonstrates the handling of task execution results. The log information is parsed and sorted, if several tasks have been executed simultaneously. If a negative test result is detected, the physicians of the patient can be alerted via several channels, such as e-mail, SMS or alert indication in web browser (further monitoring channel). The alerted physician can see the alarm reasons in the task execution history.

By a large number of the treated patients, the automatic selection of patients a progressive course of disease is very important. The system uses the optimistic approach “No news - good news”: physicians can suppose that everything is in order until alerted. They should not need to examine the data of all patients, but can access the data of patient directly, pointed to by the alert description.

Fig. 5. Interest registration of physician

The negative results can be detected either if patient has reached a card marked as critical or by statistical analysis. Thereby alarms of different types can be initiated. The physicians are able to register their interest for selected types of alarms and choose delivery channels for them. Fig. 5. shows the interest registration of physician schematically.

Only the physicians responsible for a patient have to be notified about a problem. Based on personal relations and physicians’ interest settings for each problem, for each channel, the system determines a physician subgroup, which should be alerted, and sends the notification only to the selected physicians.

For each alarm, channel (with exception of monitoring channel) and interested physician the server creates a special object containing the alarm type, problem description and data of the corresponding patient. The alarm messages contained in objects for these channels are extracted and sent out by channel handlers, the objects are destroyed afterwards. (Fig. 4. SMS and e-mail notification.)

Only one object for the monitoring channel is created even for several physicians to prevent from sending duplicated directives out to the patient. It additionally contains the duration of the alarm validity, reference to the physician responsible for handling the problem. The data of the responsible physician is not set after object creation. A list of valid alarms is accessible to the physicians per web browser. Each physician, who is able to resolve a certain type of a patient’s problem, can take responsibility for that certain alarm.

For each alarm, channel (with exception of monitoring channel) and interested physician the server creates a special object containing the alarm type, problem description and data of the corresponding patient. The alarm messages contained in objects for these channels are extracted and sent out by channel handlers, the objects are destroyed afterwards. (Fig. 4. SMS and e-mail notification.)

3. Application

MEMOS is applied to support persons having prospective memory deficits. It is successfully utilized at Outpatient Clinic for Cognitive Neurology at University of Leipzig, where it is not only used as memory aid system, but also as a platform for further neuropsychological research [1].

MEMOS has been tested with 10 patients. 80% of patients with deficits of the prospective memory have benefited from it.

4. Discussion

Monitoring ambulant patients is a subject of research of several organizations. They focus their efforts on the development of the devices, which measure specific parameters of a patient state, such as weight [4], pulse and body temperature [5]. Using Bluetooth or WLAN, the devices transmit the results to the home station connected
to the Internet [4, 5]. The diabetic patients can also upload results of their tests via Internet [6] or can use a PDA as a diary [7].

Some systems lack mobility or promptness, others need a special equipment, which can be very expensive. All these systems possess only a limited field of application.

The proposed way to build monitoring system provides guidelines for a universal system for operative mobile monitoring of patients with several diseases.

Although a direct input of measured parameter values provides precise reflection of a course of a disease, the inquiry of parameter interval can also provide the required precision of input and is more comfortable for patients than direct data input.

The system does not use any special sensors, it depends on the cooperation of patients, who have to input the data. Nevertheless, patients often write down the test results in a diary anyway, so they can transmit test results to the server additionally. Thereby, the central collection of data prevents their possible loss and also facilitates their statistical analysis.

Task description templates make the system universal, flexible and extensible: the templates can be created for diverse diseases and tests, they can be installed at runtime, the parameter bounds and statistical rules can be adjusted individually.

4. Summary

The article demonstrates a generic approach to a mobile monitoring system, applying commonly used components for early and automatic detection of a progressive course of several diseases. Application of this system helps to optimise the work of physicians, because they can now focus their effort on automatically selected patients with a progressive course of disease. The operative correction of a medical treatment for these patients can prevent complications.

References


