Medicine Tracker for Smart TV

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Abstract—In this paper we estimate relevance of Smart TV as a platform for mobile healthcare applications. Suitability estimation is based on considering the roles that Smart TV can play in mobile healthcare area and benefits it provides. On top of our analysis we propose a prototype of a mobile healthcare application. Then, we present the actual application that is being developed accordingly to these specifications. Finally, we make a conclusion about relevance of Smart TV as a platform for mHealth applications.

Keywords—*Smart TV, Mobile Healthcare, mHealth, mHealth application, Medicine Tracker.*

I. Introduction

Mobile healthcare (mHealth) can be defined as "emerging mobile communications and network technologies for healthcare" [1]. Nowadays, mHealth is popular and important research area and there are a lot of papers dedicated to various aspects of this field. However, there is very small amount of papers dedicated to roles that Smart TV can play in mHealth environment, i.e., devices and technologies that implement mHealth vision.

Smart TV device is a television set or a set-top box for the television, which provides more computing and connectivity capabilities than a basic television set. Smart TV devices in the current state are rather focused on using online services, such as on demand streaming media, over-the-top content and interactive media. Such TVs have an Ethernet port or a Wi-Fi module and can execute applications [2].

The main goal of the paper is to show how Smart TV can be used in mHealth, and to corroborate the outcomes by the example of the concrete mHealth application for Smart TV.

The paper structure is following. Section II describes advantages of Smart TV as platform for mHealth applications. It lists features that are significant for elderly people. Then it describes advantages of Smart TV as platform for mHealth application. Section III lists specification for mHealth application. Application's specification includes numerous items. First is the idea of medicine intake tracking. Second one, the system should not only store collected measurements, but also should analyze individually for each user. Third one, the system should detect emergency situations based on the analysis of entered data and handle them accordingly. Fourth one, the system should compose collected track data into reports that may be useful for the further research. Fifth feature is the variety of ways to configure the system. Last one are solutions for issues of support for multiple users. Section IV describes the Medicine Tracker application and implementation details.

Firstly, we present structure of application database. Then we list features that are already implemented. Lastly, we present the near-term development plan. Section V concludes the paper.

II. Relevance of Smart TV as platform for mHealth applications

This section describes advantages of Smart TV as the platform for mHealth applications development.

A. Elderly-friendly platform

Research shows that elderly people spend a lot of time watching TV [3]. It means that they are familiar with remote control tool. Also it might mean that they are more likely to perceive information that appears on TV screen rather than information that appears on screen of mobile phone. That is so because elderly people often leave their mobile phone in other room and do not check it regularly.

Smart TVs have large screen and support control via remote. It allows to develop applications with design that is friendly to users with no or low experience with modern technologies. Elderly people are familiar with remote TV control and they often have poor eyesight. Therefore, Smart TV has qualities that make it good platform for applications for elderly people [4].

B. Openness of Smart TV platforms and their APIs

In [2] we analyzed popular Smart TV platforms and their APIs. Almost all of them have very limited API for interacting with TV's hardware and can run only foreground Web applications. It is not sufficient for development of complex applications, because the user has to launch application manually every time she needs its functionality. It makes impossible to develop an automated application. Google Smart TV is based on Google Android, that is a mobile operating system with powerful API that allows to run applications in background. Therefore, applications can be automated to perform complex tasks.

We also distinguished roles that Smart TV can play in Internet of Things environment. Following subsections describe these roles in the perspective for mHealth application development.

C. Visualization device

TV has a big screen that makes it easy to display information that will be perceived. It is Smart TV's biggest advantage over smartphones when considering elderly people. While TV is almost always running, therefore it is hard to miss notification that appears on the large screen. Smart TV can deliver various useful data to the user, such as reminders to do something related with the healthcare and warnings about the state of their health.

D. Interaction point

There are different ways to control Smart TV, and the familiar remote control is one of them. When developing a mHealth application, it makes sense to design its interface considering the remote control and not more exotic ways like motion detection or voice control, because it is the native and familiar way to control TV [5], [6].

Smart TV can also act as interaction point for complex system that consists of several elements, such as Smart TV, smartphone, vital sign sensor, etc.

E. Data processing

One of core ideas of mHealth is the individual treatment, i.e. all of person's health measurements are compared to the same person's previous results and not to some general average values. Smart TV has enough processing power to analyze user's measurements and detect abnormalities. As stated in [7], TV is almost always plugged into the power grid, so it can continuously process incoming data.

F. Data storage

Smart TV can store sufficient amount of data to store personal medical measurements, for example, Sony NSZ-GS7 Internet Player [8], [9] has 8GB of internal memory and supports external USB drives. It is possible to keep a decades worth amount of measurement data. Such amounts of data could be useful for statistical research and creation of the personalized health model. Such information may keep a lot of hidden clues for health care researchers.

G. Data source

Smart TV can receive information via Bluetooth, USB, Wi-Fi or Ethernet from other mHealth devices. For example, it can get measurements from blood pressure meters, pulse meters and other vital signs sensors. Even smartphone can serve as pulse meter [10]. Smart TV provides means to receive data directly into an application that does further processing.

H. Section conclusion

Smart TV is elderly-friendly platform with multiple advantages such as large screen, intuitive control and sufficient processing power, storage capacity and connectivity means. Therefore, it is possible to consider development of an mHealth application that utilizes the advantages of platform.

III. MEDICINE INTAKE SYSTEM SPECIFICATION

This section describes specification we propose for our mHealth application for Smart TV.

A. Motivation

There were attempts to use TV as mHealth platform before [4]. But due to very limited processing capabilities of first Smart TV to be considered in that research, it was impossible to develop actually useful application. However, they managed to develop an application for more advanced Smart TV platform. We propose to use even more advanced Smart TV platform, Google TV [2]. It will solve the problem of lacking processing power and will allow to create effective mHealth application for Smart TV.

B. Intake and measurement tracking

When people are watching TV, they may forget about scheduled medicine intake for a series of reasons, such as outer distraction or irresponsibility. System reminds them of these intakes, first with subtle notification, and then with more insistent ways. Then the system allows to track the intake, such ideas were mentioned in [11], [12]. The following use case is the core interaction scenario for the system.

The user is considered to watch TV at the moment and the system is considered to be properly set up by a physician or relatives. The setup implies the medicine intake schedule that includes what medicine the patient should intake, when one should do it and the amount of the medicine per intake. Setup can be performed remotely (by physician) or locally (by relatives).

When time comes for the medicine intake, the system displays a notification in the top area of the TV screen and plays a short sound notification. From here, there are two possible cases:

1) The user selects notification.
2) The user ignores notification.

If the user selects the notification the medicine tracker application opens. When one performs the required action and records medicine intake through the application, the notification disappears. If the user does not add a record in 15 minutes, the application displays the notification screen in full-screen mode to attract more attention and plays longer sound notification. When the user performs the required action and tracks it through the application, the notification disappears.

This use case can be extended for other mHealth activities, like taking measurements of vital signs or performing required exercises. In these cases the click on the notification opens the corresponding application, such as a measurement tracker or an exercise helper. The time given to perform required action depends on the action type, for example, 5 minutes for a measurement and 15 minutes for an exercise.

In order to implement this use case platform must provide the following features: show notifications, store information about schedule, retrieve data from external measurement taking devices like blood pressure meter, pulse meter, glucose meter, etc. [11].

C. Measurement analysis

The system may not only track measurement results but also can analyze them [13]. This could be used to realize the

idea of the individual treatment, which is the fundamental idea of mHealth.

For example, normal blood pressure for adult is 120/80 [14], where 120 is systolic pressure and 80 is diastolic pressure, and the person is considered healthy if the one's pressure does not highly deviates from these values. However, there are three situations where this approach may give false positive or false negative results.

First situation is when the person's individual normal blood pressure is higher than normal 120/80, e.g., 130/85. After single measurement physician would suggest that the person has hypertension while one is healthy.

Second situation is when person's individual normal blood pressure is lower than normal, e.g., 110/70. It raised for some reason and became the normal 120/80, and after single measurement physician does not find any aberrant results and releases the patient.

Third situation is when person's individual normal blood pressure coincides with average 120/80, but after some point in time a trend of slight continuous growth has appeared, e.g., it was 125/85 for whole week. It is still considered normal, but it also can be a sign of an illness. The knowledge of one's normal blood pressure level may help to detect this illness at early stage and even prevent some serious consequences.

The individual approach does not have these flaws, because when person's vital signs are measured regularly, the application can calculate the individual normal values.

The system creates great opportunity to implement this approach. It constantly reminds person to take measurement, tracks it and compares to previous results. It allows to create a personalized health model and detect deviations.

D. Emergency situation handling

If the system detects an abnormal measurement [3], it can deal with it in different ways, depending on the danger degree.

If the deviation from normal value is slight and it is the first occurrence, it is sufficient to just display a notification that informs the user of this discrepancy.

Next level of danger is the slight continuous deviation. It could mean that something is wrong with the patient , so the system suggests to attend a hospital and also sends these measurement results to the person's physician.

If the system detects severe single deviation, e.g., very high blood pressure, it sends an emergency signal to the ambulance service, the person's physician and relatives. These measures are taken because the person is probably not capable to make these calls on one's own.

If the patient fails to track the measurement in the specified period of time after the scheduled time, e.g., 12 hours, and one did not notify the system that she is leaving, then the system notifies the person and the one's physician and relatives via cell service. If none of them informs the system that the person is fine, it sends the same emergency signal about severe deviation that was mentioned in previous paragraph.

E. Report generation

The system collects and analyzes vital signs measurements. The system can receive these data from monitors via Bluetooth [15], [16]. There could be some hidden information about correlation of medicines and vital signs that the system does not process. This information is contained in the intake and measurement log. It could be very useful for various statistical research. Report generation tools can also be used by physician and relatives to check on the patient. For example, system can send reports to physician and relatives via e-mail or upload them to some cloud storage.

In order to simplify the retrieval of this data from local data storage, the system can generate reports periodically or on demand. Reports contain both processed and raw data. Raw data is simply basic information that the system has collected, such as measurement results, timestamps, etc. Processed data is more complex and includes such values as missed measurements and intakes, amount of time that passed between issuing a reminder and adding the track record to the log, etc.

F. System configuration

There are a lot of configurable settings in such system, such as medicine intake and measurement schedule, time spans between notification issue and full-screen alert, between the last user's interaction with the system and raising an emergency notifications, etc.

There are 3 possible approaches to setup the system. The most basic one is to use the configuration interface of the application directly on Smart TV. This method can be used by person's relatives and it is efficient if the setup should not performed frequently, e.g., the person should intake some medication for several months.

More advanced scenario involves the configuration of Smart TV application from another device, such as a smartphone or a personal computer. This approach can be used by person's relatives if they have to change configuration frequently or by person's physician if one does not have too many patients that use this system. The advantage of this approach is that the person who performs setup does not have to visit patient.

The most advanced scenario is the use of the centralized web service to setup lots of applications. When the physician issues a prescription the system automatically creates corresponding rule for the person's schedule, and a prescription is forwarded to the nearest drug store.

G. Separate tracks for each person

There are cases where Medicine tracking application is used by more than one user, e.g., elderly couple. This situation may create inconvenience for users because they may mix up medications or because two or more intake times coincide.

We propose a simple solution for issue with mix up, it is enough to just add the large photo of the person and the large label with person's name on it to the alert screen. This way when notifications is shown, the user clearly sees, who should intake medicine and what medicine she should intake.

TABLE I.   USERS

Name	String
Photo	String
E-mail	String

TABLE II.   MEDICINES

ID	int
Name	String
Dose Type	int
Picture	String
Description	String
Intake Procedure	String
External Description	String

TABLE III.   DOSE TYPES

ID	int
Name	String

TABLE IV.   SCHEDULE

ID	int
User ID	int
Medicine ID	int
Dose Amount	int
Time	String
Days	String

As for the issue with intake times overlapping, it is possible to issue composite notification that contains multiple items and allows to choose them in arbitrary order.

H. Section conclusion

We described specifications for the medicine intake tracking mHealth application for Smart TV. Its functionality consists of several items, such as intake and measurement notifications, analysis of measured data, emergency situation handling, report generation, various approaches to setup application and support of multiple users. The next section shows how these specifications were implemented in an actual application.

IV.   MEDICINE TRACKER APPLICATION

This section describes the application that is currently under development and implementation decisions, architecture details, etc. Application is being developed for Google Android TV platform because it is most advanced Smart TV product and the only one that allows applications to run in the background [2]. This feature is essential for the application because it must be able to issue notification when the person is using TV in some way that makes the application to not run in foreground.

A. Database

This section describes how application stores various data such as information about users, medicines, schedule and intake track log.

1) Database scheme: Database consists of five tables: Users, Medicines, Dose Types, Schedule and Intake Log. Tables I, II, III, IV, V show structures of these tables. We will give the description for most important fields of these tables.

TABLE V.   INTAKES

ID	int
User ID	int
Medicine ID	int
Dose Amount	int
Time Stamp	String

a) Table Users: *E-mail* is the unique identifier of every person in the centralized web service described in chapter III-F.

b) Table Medicines: *External Description* is URL that leads to an external resource that contains detailed description of the medicine.

There are plenty of medicine that has several versions that differ only in the amount of active ingredients. For example, pills containing 25mg of active materials and pills containing 50mg of active materials, so the patient could take either two pills of the first or only one pill of the second one. Table contains different entries for each variant of particular medicine.

c) Table Dose Types: For medicines having liquid form it is appropriate to use words associated with intake of such medicines, such as "spoon" or "drop".

d) Schedule: Field *Days* is a specially formatted string, that determines recurrence type of the intake. It can hold the following values:

1) Daily, e.g., intake happens every *n* days. Then *Days* is formatted like "daily[n]".
2) Selected days of week, e.g., single day, interval of days, even or odd weeks. *Days* is formatted like "selected[even, monday-friday]".
3) Hourly, e.g., every *n* hours, but not more than *k* times per day. *Days* is formatted like "hourly[n, k]"

Multiple recurrence types may be specified at once, for example, "daily[2], hourly[4, 5]". In this example, medicine should be taken every second day 5 times per day with an interval between intakes of 4 hours.

The start date and the end date are stored in *Days* field and are optional. If the start date is missing, then rule will be active from the moment of its creation. If the end date is missing, then rule will be active until it is changed.

2) Content provider: Google Android provides a hack to provide access for several activities to data stored in a database, called content provider. It encapsulates the actions with database and facilitates information exchange with other applications. The detailed description of content providers can be found on Google's developer network [17].

From the technical point of view a content provider is a class implementing the interface that consists of methods *query*, *insert*, *update* and *delete*. The common argument of these methods is URI that identifies the specific table to interact with. The specific argument for *query* method is the string that contains an SQL query. The specific argument for *insert* and *update* methods is the object of *ContentValues* type, it is the standard type to store pairs of keys and values in the Android database implementation. The specific argument for *update* and
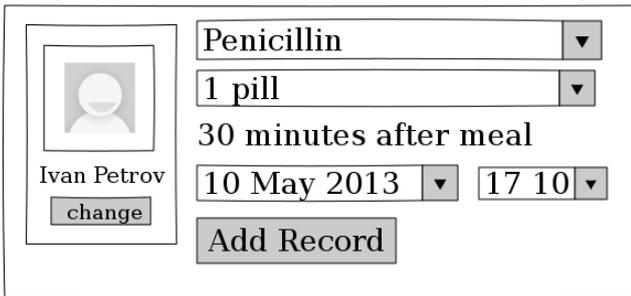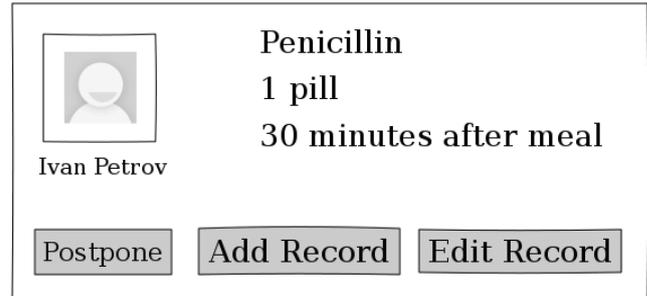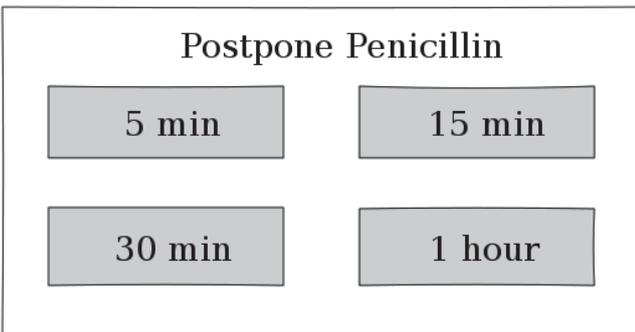
Fig. 1.   Track Screen

Fig. 2.   Postpone Screen

Fig. 3.   Alarm Screen

delete arguments is ID that determines specific table row to modify.

Since the application's database has several tables, we need to distinguish 10 different URI types: 5 for query of table and 5 for query of specific table row. To simplify code, we use the map that matches integer URI type with table name.

B. Implemented functionality

This section describes features that are present is the first released version of the application Medicine Tracker for Smart TV. Current functionality includes tools for setting up and storing the intake schedule, the service for issuing notifications, the screen that allows to add a record and the screen that displays the intake log. Interface sketches are presented on figures IV-B, IV-B and IV-B. Interface is designed to facilitate application use for elderly people. It is largely scaled and can be intuitively controlled via remote.

1) Schedule setup: Schedule is displayed with help of SimpleCursorAdapter class. Basically, this class fills specified interface layout defined in XML with data from query to database. Content provider allows to use callback loader that automates refreshment of list that contains rows from table.

Actions *Add*, *Edit* and *Delete* are available through context menu that can be invoked by click on list item. *Delete* action deletes the selected item from the database. *Add* action and *Edit* action invoke the dialogue that allows the user to enter required data. When the user entered all information and pressed *OK* button the application adds inputed data to the database.

2) Notifications: When the user launches the application, it starts a background service that will continue to work even when the user exits the application. This service calculates the next intake time and sets an alarm with this time. When the alarm activates, it sends system broadcast message that can be handled by the specified class, which is created by developer.

The class builds and shows the Android notification [18]. If the user clicks on this notification, then *Track* screen appears, see Figure IV-B. Otherwise, if one does not click on the notification for 15 minutes, the screen that allows to track or postpone intake appears, see Figure IV-B. If the user chooses to postpone medicine intake, Postpone screen appears, see Figure IV-B. Each of this events restarts the background service, making the system work automatically.

3) Track screen: Track screen allows to add a record to the intake log. There are two situations when the user wants to add a record. First one is when notification appears, and the user immediately tracks the intake. Second one is when the user took the medication, but was away from Smart TV, e.g., during lunch at work. Application uses the same screen in both situations.

The screen displays the large photo of the person that should intake the medicine and allows to change it. It also displays a dropdown list that contains all medicines that the specified person should intake, an editable field for the amount of the medicine and the date and time picker.

When the user clicks the *Add* button, entered data is added to the *Intake Log* table and Track screen closes.

4) Track log view: This screen can be accessed through the application's main menu and it displays contents of *Intake Log* table. Implementation utilizes same technologies as *Schedule setup* screen, such as SimpleCursorAdapter and loader callbacks.

C. Application development directions

This section describes features that will be implemented in future application releases.

1) Report generation and statistics: The application can gather various statistics, from the amount of intakes to more advanced values such as the mean time between notification and the medicine intake, the amount of completely missed intakes or the influence of certain medications on vital signs of the specific person. However, application should be able to track vital signs first.

To calculate the mean time that passes from the notification issuing till adding of the track record to database, the application has to store timestamps of the issuing original notification. This is because when the user postpones intake, background service and sets different time to issue notification. However, application needs the original notification issue time to properly calculate time between issuing notification and tracking intake.

To calculate the amount of completely missed medicine intakes, the application must be able to determine whether the person is in another room and does not perceive notification or the person is not at home at all, e.g., at work. Simple solution for this is configurable timeouts. If the person does not respond to postpone screen within 15 minutes, application starts playing sound. If the user still does not respond in 15 minutes, one is considered absent and intake is considered missed unless one tracks it from track screen mentioned in chapter IV-B3.

Calculating the influence of medications on vital signs of the specific person requires sufficient amount of data collected before and after the person starts to intake certain medication and can not be precise enough to diagnose anything. However, if amount of measurements is large and pattern is consistent, such statistics may be helpful for physician.

Application also should transmit reports to the person's physician and relatives. There are two ways to accomplish it. First one is to send reports via e-mail to the specified addresses. Second one is to upload reports to some cloud server, which can store reports from multiple Smart TVs and provide centralized access to them.

2) Configuration from external devices: In most cases it is not efficient to use application's local configuration tools, it is better to connect an external device that can configure the application. To make the system able to receive its configuration from external device, the most important part is adding support of network connectivity. Then, there are two different ways to enable this approach to configuration.

First one is connecting to the other Android device such as smartphone or tablet and creating rules using local tools, described in IV-B1. This connection can be established both in local network and via Internet. The flaw of such approach is that both devices must be on-line simultaneously, i.e., if the patient's device is off-line because of unstable Internet connection or power blackout, it is impossible to change their schedule. So the person's relative or the physician will be forced to wait until the moment when the desired device is on-line and even then other issues may occur. These issues may occur because of unstable Internet connection on any of sides, and process of configuration may take too much time and effort. This approach may not work at all if patient's Smart TV is located in local router network that prevents it from establishing a peer-to-peer connection.

Second one is using the batch processing and Google Cloud Messaging for Android (GCM) [19]. Batch processing means executing a series of tasks without manual intervention. GCM is a service that allows to send data from server to Android-powered device. So the idea is to form a series of commands that have to be executed on the person's device and send them to the device via GCM. This approach reduces the time required to edit schedule to minimal because both sides do not have to wait for each other. It also scales better for centralized web service case described in III-F.

V. CONCLUSION

Smart TV may strongly improve the acceptance rate of mHealth for elderly people, one of the most health care dependent social group, because they are more familiar to TV interface rather than to smartphones.

There were attempts to use TV as mHealth platform before [4]. But due to very limited processing capabilities of first Smart TV to be considered in that research, it was impossible to develop actually useful application. However, they managed to develop an application for more advanced Smart TV platform. We propose to use even more advanced Smart TV platform, Google TV [2]. It will solve the problem of lacking processing power and will allow to create effective mHealth application for Smart TV.

One of such applications is "Medicine Tracker for Google TV". Currently it serves for pure research goals, but development is already at pre-release stage. After its release, we can continue further development and scientific research, e.g., acceptance of the application for elderly people study.

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