ABSTRACT
The availability of mobile information and communication technologies is increasing rapidly and provides huge opportunities for home monitoring applications in particular for outpatients and patients suffering from chronic diseases. Because of the high availability of mobile phones [1] these devices could be used as the home monitoring terminal (HMT) of choice to provide a basis for interaction between patients and caregivers. The most challenging part still is the patient terminal, i.e. to provide the user with a method to enter the measured data into the system. The objective of this paper is to present and compare solutions for mobile phone based HMT using textual input via numeric keypads as well as to present a unique approach to the human computer interface challenge which is based on digital camera enabled mobile phones and Multimedia Messaging Service (MMS).

KEY WORDS
Patient Monitoring, Human Computer Interaction, Telemedicine, Ubiquitous Computing, eHealth

1. Introduction
Patients suffering from chronic diseases are asked to track their key measures like blood pressure, pulse, diabetes relevant data or events by daily writing them down into lists, tables and diaries. The captured data are expected to show trends in the illness patterns and to help the doctor in guiding the patient to the best possible health status. However, patients’ compliance using the conventional method in self-management is often poor and the interpretation of the hand written data is difficult and time consuming [2].
Therefore an easy-to-use and home based data acquisition system would be helpful in guiding the patient through the process of data capture and self management. The basic idea is to track the patient’s personal health status using a mobile phone based HMT and to send the data to a remote monitoring centre. An automated monitoring process compares the values and trends with patient specific thresholds, gives feedback to the patients and turns the doctor’s attention to the patient when necessary by means of notifications and alerts [3,4,5].
The objective of this paper is to present and compare various mobile phone based data acquisition methods currently used in clinical studies and to identify aspects of usage of those methods in daily life.

2. Methods
In close cooperation with our clinical partners we developed a patient centered remote monitoring concept for regular and home based measurement and transmission of health parameters like blood pressure, body weight, symptoms, and medication. The system has been built using mostly standard components and state-of-the-art Internet technology. Basically mobile phones offer several technical approaches for the usage as HMT. These devices provide
a wide scale of possibilities for entering data on- or offline to the system via numeric keypad.

Most of the standard mobile phones support an online connection to a monitoring center via WAP (Wireless Application Protocol) browser. The WAP browser prompts the user to enter data into an input template generated by WML (Wireless Markup Language) - syntax. If there are more inputs necessary, the user has to browse through the data entry pages to complete the data acquisition process.

Smart phones (e.g. NOKIA 3650) allow to install and run software applications, like the Opera HTML (hyper text transfer protocol) micro browser [6]. Special style sheets, which are able to convert the content of standard web pages or input forms to the small display format are used in order to optimize usability and abridgement. In both cases an online connection to the monitoring server is necessary.

Because of this limitation the J2ME platform (Java 2 Micro Edition, SUN Microsystems) has been used to develop a stand-alone application with remote synchronization running on Java enabled mobile phones. In the first step the collected data are stored directly into a local database. From time to time the user starts a synchronization process via HTTP request and GPRS data transfer.

Table 1: Results of clinical studies

<table>
<thead>
<tr>
<th>Study</th>
<th>N (female)</th>
<th>mean age</th>
<th>Protocol</th>
<th>Cumulative monitoring period [days]</th>
<th>Cumulative transfer session</th>
<th>Drop outs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardio-Memory</td>
<td>20 (1)</td>
<td>50</td>
<td>WAP</td>
<td>1.800</td>
<td>2.040</td>
<td>1</td>
</tr>
<tr>
<td>Diab-Memory</td>
<td>10 (4)</td>
<td>36.6</td>
<td>HTTP</td>
<td>2803</td>
<td>11.028</td>
<td>0</td>
</tr>
<tr>
<td>MOBITEL (running)</td>
<td>21 (9)</td>
<td>63.4</td>
<td>WAP</td>
<td>4010</td>
<td>3.677</td>
<td>3</td>
</tr>
<tr>
<td>MoniCam</td>
<td>5</td>
<td>30</td>
<td>MMS</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 1 shows the results of four studies focusing on the management of chronic diseases which have been performed by using various mobile phone based HMT to acquire and to transfer recorded health data to the monitoring centre [8,9,10,11]. N(female) represents the number of patients participating in the study. Cumulative monitoring period means the sum of the number of days from the first to the last successful data transmission for all patients or test subjects, respectively. Cumulative transfer sessions indicates the overall number of data sets transmitted successfully to the monitoring center. Drop outs indicate the number of patients who stopped the data acquisition process prematurely.

1. Cardio-Memory

Twenty patients suffering from hypertension or heart failure were ask to record daily blood pressure values, heart rate, body weight, and well-being in the morning and to transfer the data via WAP browser using the MOTOROLA Timeport 280 mobile phone. The mean age was 50 (40.5 – 60.3) years and one patient has to be excluded because of amblyopia.

2. Diab-Memory

Textual input via numeric keypad implies basic knowledge in handling a mobile phone. Therefore we developed an unique approach to the human computer interface challenge which is based on digital camera enabled smart phones and MMS. A special software developed for Symbian OS [7] guides the user in taking a photo of the display e.g. of the blood pressure meter device as well as to send the photo automatically to the health monitoring centre via MMS with no more then two keystrokes. A special character extraction algorithm starts to process the photo in order to extract displayed values, which are finally stored within the database.

3. Results
Diabetes mellitus type 1 patients (10 participants) collected all disease relevant data (blood glucose, bread unit, insulin dose, well-being, activity) at least three times up to ten times a day by using a Java based software application running on NOKIA 7650 smart phones resulting in a cumulative monitoring period of 2803 (280±145) days and a amount of 11.028 (1103 ± 824) data transfer sessions.

3. MOBITEL

In the scope of a randomized, multi center trial heart failure patients have been asked to acquire blood pressure values, heart rate, weight, well-being, and individual medication by means of WAP technology. Because of the relatively large display and a numeric keypad which can be used with relative easy the NOKIA 3510i mobile phone was used as HMT of choice.

Up to now 29 patients (mean age 63,4 years) were randomized into the telemonitoring group and asked to transfer their daily measurements to the monitoring center.

4. MoniCam

A group of 5 test users were asked to take and transfer a photo of the display of blood pressure measurement devices with different camera enabled smart phones (Nokia 3650, 6600, 7650) to the monitoring center where automatic character extraction took place. Depending on the type of measurement device a rate of more than 95% of correctly detected values could be reached.

4. Discussion

Because of the ubiquitous availability of mobile phones these devices are poised to be the HMT of choice to provide an interface to the remote monitoring system. The most challenging part is still to provide the user with a method to enter the measured data into the system.

Ideally, a mobile phone based HMT would have the following properties:
1. easy to learn and use (elderly, technically very unskilled and even handicapped people should be able to use the method intuitively)
2. low-cost (should be based on technology universally available without significant set-up expenses or extra costs)
3. error-resistant (allowing source data verification and leave no or very little room for data transcription errors)
4. off-line data acquisition (the data should be stored temporally on the mobile device and could be sent postpone in case of lack of network availability)

Table 2 gives an overview on the properties of the various methods of human computer interaction used in different clinical studies as outlined in Table 1. Three studies have been performed using the mobile phones’ numerical keypads as input devices of choice. Especially elderly patients participated in the Cardio-Memory and in the MOBITEL study reported problems in cognition of the small display by entering data via WAP browser and numerical keypad. This results in a huge number of type and transmission errors and a high drop out rate. Therefore, the usability in using the WAP browser for data input is rather low as compared to the other methods. Because of these limitations in usability using WAP/WML as well as HTTP/HTML based input forms, a special JAVA based software, running on smart phones has been developed. This application provides a user-friendly and intuitive GUI (metaphoric, colourful) for entering diabetes related data (blood sugar, bread units, insulin dose, etc). This is of special importance to such patients since they usually have to record those data a couple of times per day. Feded values were also checked for plausibility and - in case of an error - a warning message was given in order to improve error resistance. Local storage of data provides also the possibility to postpone the transmission of data in case of lack of network availability.

However, both technologies imply basic knowledge in handling a mobile phone and using the numeric keypad. Using the integrated camera for data acquisition provides a very intuitive method for data acquisition especially for elderly and technical unskilled people. The proposed method is actually very easy-to-use, given that most people are used to take photos. If the current trend persists, a large number of mobile phones will have the necessary technical features required to perform this procedure in the near future at almost no extra costs.
An advantage of the MMS based data transmission is that—opposite to WAP-based concepts—if an online connection to the data carrier service (GPRS, UMTS) at a given location and time is not available, the mobile phone will try to send the data repeatedly until the message has been sent successfully (as is the case with SMS as well). On the other hand it turned out, that this solution is not very adaptable to specific scenarios compared to other methods as shown in Table 2. For example to acquire extra parameters like weight, medication or well-being, essential items in monitoring heart failure patients, an additional effort has to be done to provide the user with a GUI for textual input.

Considering the costs, we learned, that using a standard mobile phone with WAP browser provides the cheapest solution for using the mobile phone as HMT. This is particular the case compared to the MoniCam solution, where a camera and MMS enabled smart phone is necessary. Costs for data transmission via GPRS are also comparatively low in opposite to sending a picture MMS with the display of the measurement device.

5. Conclusion

Currently, no method exists which fulfils all criteria of a user friendly, easy to use as well as adaptable and extendable HMT, in particular, if costs are also considered. Therefore, additional efforts have to be made to identify emerging technologies like NFC (Near Field Communication) or RFID (Radio Frequency Identification) and to find out how such technologies could be utilized for patient centered health data acquisition using mobile phones.

References: