Today, how was your ability to move about?

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Abstract. In this paper, we are interested in monitoring mobility activities in order to automatically assess quality of life of people. In particular, we are aimed at answering to the question "*Today, how was your ability to move about?*". To this end, we rely on a sensor-based telemonitoring and home support system. Although we are interested in assisting disabled people, we performed preliminary experiments with a healthy user, as a proof of concept. Results show that the approach is promising. Thus, we are now in the process to install the system in disabled people's homes under the umbrella of the BackHome project.

1 Introduction

Improving people's Quality of Life (QoL) is one of the expected outcomes of modern health applications and systems. Thus, several solutions, aimed at improving QoL of the corresponding users, have been investigated and proposed [2]. Among the huge kinds of proposed solutions, let us focus here on those that provide telemonitoring and home support [1], [3], [5]. TeleMonitoring and Home Support Systems (TMHSSs) help users (e.g., disabled or elderly people) to live normally at home keeping (or returning to) their life roles. On the other end, they support health care providers in the task of being aware of the status of their patients.

To assess users' QoL, in the literature several questionnaires have been proposed and adopted [6], [10], [4], [15], [8]. Users are asked to answer to a predefined set of questions about their mental and psychological status and feeling. Although they are largely adopted, as noted in [11], answering them could become tedious and annoying for users and could even be impossible in cases of severe impairment of the user.

In [13] we proposed a generic methodology aimed at automatic assessing QoL of users. Starting from that methodology, among all the items that may compose a QoL questionnaire, in this paper we focus on how to assess the ability to move about. In fact, we use information gathered from a sensor-based TMHSS to answer to the question "*Today, how was your ability to move about?*". Although several works study how to recognize activities [9] and behavior [7], to our best knowledge, this is the first attempt to use that information to automatically assess a (part of a) QoL questionnaire.

2 Materials and Methods

In [13] we proposed a generic methodology to assess and telemonitor QoL of individuals with a holistic bio-psycho-social approach, which intends to become the base for current and future telemedicine and teleassistance solutions. Since the overall proposal is very ambitious, in this paper, we focus on the task of assessing just one of the items of a given questionnaire. In other words, we show and discuss our implementation to assess movement ability.

2.1 The Methodology

To monitor QoL, we propose a sensor-based TMHSS able to monitor the evolution of the user's daily life activity, providing QoL automated assessment based on information gathering and data mining techniques [14]. Specifically, wearable sensors allow to monitor fatigue, stress, and further user's conditions. Environmental sensors are used to monitor –for instance– temperature and humidity, as well as the movements (motion sensors) and the physical position of the user (location sensors). Smart home devices enable physical autonomy of the user and help her/him carry out daily life activities. From the social perspective, an Internet-connected device allows the user to communicate with remote therapists, careers, relatives, and friends through email and social networks (i.e., Facebook and Twitter).

Starting from the standard EQ-5D-5L questionnaire, we propose and adopt a visual analogue scale QoL questionnaire. The proposed questionnaire is designed to assess the key QoL features of an individual, which correspond to the main features that we aim to monitor. In other words, we consider the user's QoL as the conjunction of the following items: *Mood*, *Health Status*, *Mobility*, *Self-care*, *Usual Activities*, and *Pain/Discomfort*. As already said, in this paper we focus only on user's movement ability, i.e., *Mobility*. In other words, we aim to automatically reply to the question "*Today, how was your ability to move about?*".

2.2 The Implemented Telemonitoring and Home Support System

The implemented TMHSS is able to monitor indoor and outdoor activities.

Indoor activities are monitored by relying on a set of home automation sensors. More precisely, we use motion sensors, to identify the room where the user is located (one sensor for each monitored room); a door sensor, to detect when the user enters or exits the premises; electrical power meters and switches, to control leisure activities (e.g., television and pc); pressure sensors, to track user transitions between rooms; and bed (seat) sensors, to measure the time spent in bed (wheelchair). From a technological point of view, the sensors are based on the z-wave wireless standard, which establishes a wireless mesh network of devices to send the measured data to a central unit located at user's home. That central unit collects all the data and sends them to the cloud where they are stored and analyzed. The system also comprises "virtual devices", which are software elements that fuse together information from two or more sensors in order to make some inference and provide new information. In so doing, the TMHSS is able to perform more actions and to be more adaptable to the context and the user's habits. In other words, virtual devices have been introduced to merge the information gathered by the installed real sensors.

Outdoor activities are monitored using the user's smartphone relying on Moves[1], an app for smartphones able to recognize physical activities (such as walking,

[1] http://www.moves-app.com/

running, and cycling) and movements by transportation. Moves is also able to store information about the location in which the user is, as well as the corresponding performed route(s). Moves provides an API through which is possible to access all the collected data.

2.3 How to Assess *Mobility*

Information gathered by the sensors is used as classification features to build a multi-class supervised classifier; one for each user. We considered the following features: (i) time spent on bed and (ii) maximum number of continuously hours on bed, extracted from the bed sensor; (iii) time spent on the wheelchair and (iv) maximum number of continuously hours on the wheelchair, extracted from the seat sensor; (v) time spent in each room and (vi) percentage of time in each room, extracted from the motion sensor; (vii) room in which passed the most of the time, inferred by the virtual device; (viii) total time spent at home, extracted from the door sensor; (ix) total time spent watching the TV and (x) total time spent using the PC, extracted from the corresponding power meters and switches; (xi) number of kilometers by transportation, (xii) number of kilometers by moving outdoors on the wheelchair and (xiii) number of visited places, given by Moves.
To train and test the classifier, the user is asked to answer to the question "Today, how was your ability to move about?", everyday. User's answer is an integer number in a scale from 1 to 5 that correspond to user's satisfaction in her/his movement ability. User's answers are then used to label the entries of the dataset for training and testing into three categories: "Low" (1-2), "Normal" (3) and "High"(4-5).

3 Preliminary Experiments and Results

The TMHSS presented in this paper is part of BackHome[2], an European R&D project that aims to provide a TMHSS using Brain Computer Interfaces (BCI) and other assistive technologies to improve autonomy and QoL of disabled people [12] [14].
The system is currently running in a healthy user's home in Barcelona. The corresponding user is a 40-year-old woman who lives alone. This installation is currently available and data continuously collected. According to the home plan, the following sensors have been installed: 1 door sensor; 3 motion sensors (1 living room, 1 bedroom, 1 kitchen); 3 switch and power meters (1 PC, 1 Nintendo WII, 1 kettle); and 1 bed sensor. Moreover, the user has installed in her iPhone the Moves app.
To test the feasibility of the approach, we considered a window of three months (February '14 – April '14) and made comparisons of results for three classifiers: decision tree, k-nn with k=1, and k-nn with k=3. During all the period, the user answered to the question "Today, how was your ability to move about?" daily at 7 PM. Answers have been then used to label the item of the dataset to train and test the classifiers built to verify the feasibility of the proposed QoL approach. Given a category, we consider as true positive (true negative), any entry evaluated as positive (negative) by the classifier that corresponds to an entry labeled by the

[2]http://www.backhome-fp7.eu/backhome/index.php

user as belonging (not belonging) to that class. Seemly, we consider as false positive (false negative), any entry evaluated as positive (negative) by the classifier that corresponds to an entry labeled by the user as not belonging (belonging) to that class. Results have been then calculated in terms of precision, recall, and F_1 measure.

Let us stress the fact that in this preliminary experimental phase, we are considering data coming from a healthy-user. Thus, while analyzing data, the following issues must be considered: tests have been performed with only one user; the user is healthy; and a window of less than 4 months of data has been considered. As a consequence, results can be used and analyzed only as a proof of concept of the feasibility of the approach.

The best results have been obtained using the decision tree. In fact, in that case, on average we calculated a precision of 0.64, a recall of 0.69 and a F_1 of 0.66. It is worth noting that, as expected (the user is healthy and not have difficulty in movements), the best results are given in recognizing "Normal" mobility. In fact, in this case we obtained a precision of 0.80, a recall of 0.89 and an F_1 measure of 0.84. The same behavior has been noted in the results with the k-nn classifiers, even if in that case average results are lower: precision 0.53, recall 0.56 and F_1 0.52. Also in that case, the best results are given in recognizing "Normal" mobility. In our opinion, results given by the decision tree are better than those given by the k-nn classifiers because of the very few number of data (a window of three months has been considered) and also because decision trees are more robust with respect to outliers.

4 Discussion

The methodology proposed in [13] is aimed at automatically assessing quality of life of disabled people. Relying on that methodology, in this paper, we considered the task of assessing the questionnaire item *Mobility*. A telemonitoring and home support system has been implemented to monitor both indoor and outdoor activities. Currently, the system is installed in a healthy user's home in Barcelona. Preliminary results show that the system is able to collect and analyze data useful to learn user's habits and it looks promising to assess the *Mobility* of a given user. Although, as mentioned above, preliminary results can be used only as a study of the feasibility of the approach, they are promising and encourage us to continue with the study. In fact, using also data coming from social activities (i.e., mailing, Facebook and Twitter), we started new experiments to assess also the questionnaire item "Mood".

As for the future work, the next step consists of experimenting the proposed approach under the umbrella of BackHome. Hence, we are currently setting up the proposed telemonitoring and home support system at BackHome real end-users' homes at the facilities of Cedar Foundation[3] in Belfast.

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[3]http://www.cedar-foundation.org/

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