An Arduino based Health Monitoring System for Elderly People Living at Home
Functions and Ontology

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Abstract: In recent decades, people, especially the older ones, try to live at home in autonomous way. For this purpose it is useful to monitor their vital signs and the environment that surrounds them with the aim of activating suitable environment regulation and when needed to send alarms to family members, medical, or hospitals, according to the criticality of the subject. The paper aims at proposing a flexible and reliable monitoring system based on Arduino shields. The main feature of the system is that it allows the doctor and family members to monitor the patients at distance using their mobiles. A suitable communication with the first aid center is foreseen for a fast rescue of the patients in case of critical situations. The general user model ontology is used so that the personal data featuring the patients and the relevant context may be used by any diagnostic and first aid software, thus envisaging an open and interoperable health monitoring system for elderly people living at home.

1 INTRODUCTION

With the increasing number of elderly people willing to live independently, it could be helpful to monitor their behaviour and to check in real time their health conditions. Also, it could be necessary to have automated systems that adapt the environment conditions to the people health status. Such a system should inform the family or the doctor about the possible critical health conditions, and should be able to send alarms to the hospital including the user health data and the best path to rescue the patient if the conditions are very critical.

Several proposals are available in the literature, e.g., (Huo H., 2009), but the patient data cannot be downloaded, processed and visualized at distance by using fixed and mobile devices, neither the home environmental conditions are taken into account. Therefore, aim of the paper is to show how a monitoring system of the health status of elderly people living at home may implemented by an Arduino platform to carry out both a first diagnosis of the health status and to adopt changes of the home environment parameters, e.g., home temperature and humidity, to improve life condition in the home. Sect. 2 shows how the proposed E-Health Monitoring System based on the Arduino platform (Banzi M., 2008) may check the elderly people health status. In the paper, we focus our attention on the monitoring of parameters that cannot be made by wearable sensors such as blood pressure and respiratory rate, but it could be possible to extend the monitoring to the other vital signs taken while the patient is walking by using the system illustrated in the companion paper (Pino C., 2014).

Sect. 3 illustrates how the E-Health System could be expanded with an Environment Conditions Monitoring System and how it is possible to change the environmental home conditions according to the health status and to alert family members, the doctor or even the hospital just in case the environment changes don't produce the desired positive changes of the monitored vital signs.

Sect.4 proposes to store all the mentioned information according to the general user model ontology (GUMO) (Heckmann D., 2005) so that the personal data featuring the patients and the relevant context may be used by any diagnostic and first aid software independently on the computing system in which the software resides, thus envisaging an open

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and interoperable health monitoring system for elderly people living at home. Concluding remarks illustrate open problems and future works.

2 E-HEALTH MONITORING SYSTEM

The implementation of automated and intelligent system that carries out the monitoring of the vital parameters may enhance and support the quality of life of the people, especially the elderly ones that, in recent decades, are willing to live at home in autonomous way. Our health monitoring system architecture, drawn in fig.1-up, is able to measure the blood pressure and the respiratory rate with respect to the home environmental conditions. The nucleus of the system consists of an Arduino Mega shield powered by the e-health Arduino sensor shield shown in in fig.1-down.

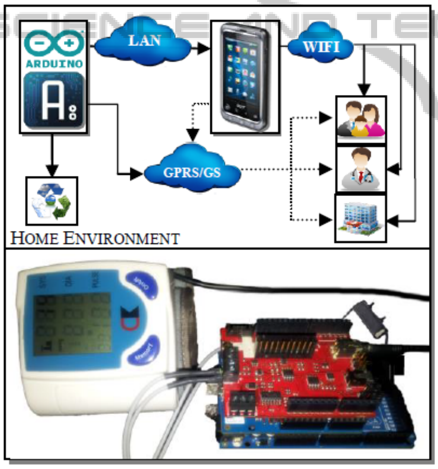


Figure 1: a) Arduino based monitoring system Architecture tracks the user vital signs and sends this information to their mobile. Also, it tracks environment condition and, if is necessary, changes them according to the health status of the user. b) E-Health Monitoring System based on Arduino.

Other two portable monitoring devices, i.e., the glucometer and the oxygen in the blood, may extend the blood pressure and respiratory sensors taken into account in the papers. Due to the reduced dimensions and costs with respect to the ones available in literature, e.g., (Islam M., 2012), all the mentioned sensors are easily portable from a location to another in the house, whereas other wearable sensors could be added as illustrated in (Pino C., 2014) to monitor the patient while moving at home.

The main feature of the proposed system is that it is able to send in real time the collected data to the doctor, to the family members, or, if the patient data are critical, to the nearest hospital using the simple and reliable communication channels pointed out in fig.1, i.e., through the GPRS/GSM and LAN shields mounted at the top of the Arduino mega shield.

In both cases, the system is provided with an internal memory where recent health data are stored. In the GPRS case, the relevant data and alarms are sent directly to the family members, to the doctor and possibly to the hospital. In the LAN case, the system sends data and alarms by means of a cellular phone connected to the LAN.

Of course, the former solution is more reliable and does not suffer of battery problems. The second could not work if the cellular phone battery is low, but it is more flexible since it may host a specific diagnostic software that avoids both false positives and negatives by executing further tests on the patient conditions. Therefore, both GPRS and LAN shields are recommended so that the system may meet reliable and flexible requisites.

The functions to take the current values of the systolic and diastolic pressures are embedded in the systems and can be recalled as shown in fig.2.

```
int systolicPressure() {
     return eHealth.getSystolicPressure();
}

int diastolicPressure() {
     return eHealth.getDiastolicPressure();
}
```

Figure 2: Functions to retrieve systolic and diastolic pressures.

The other functions to take into account to measure the rate of airflow breathed in and out, as well as the wave of the respiratory rate are shown in fig.3.

To visualize these values, the monitoring system could be provided with a small display, but we have implemented on the mobiles a software, developed with Flash Builder (Corlan M., 2009), that is able to display the above vital parameters, as shown in fig.4.

Let us note that the monitoring system is able to send to a mobile the data according to the JSON format within anonymous messages as envisaged in (Anciaux N., 2013), but to generalize its functionalities we have implemented three important functions on the mobile: a) the conversion of the received JSON strings to XML/RDF triples, b) the storage of the triples into the mobile memory and c) the triple visualization on the mobile display using a

```
int respiratoryRate() {
    return eHealth.getAirFlow();
}

void airFlowWave(int respiratoryRate) {
    eHealth.airFlowWave(respiratoryrate);
}
```

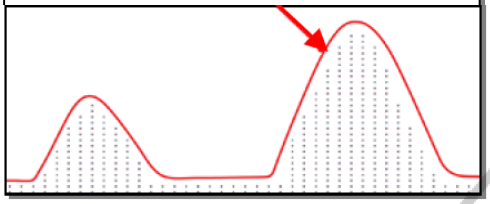
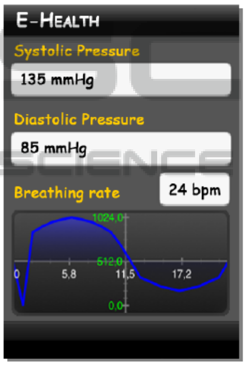


Figure 3: Functions to retrieve respiratory rate and airflow wave.




```
{"HEALTH": {
  "DATETIME": {
    "HOUR":"16",
    "MINUTE":"54",
    "SECOND":"47",
    "DAY":"29",
    "MONTH":"6",
    "YEAR":"13" },
  "BLOOD": {
    "SYSTPRESS":"135",
    "DIASPRESS":"85" },
  "BREATH": {
    "RATE":"24" }
  }
}
```


Figure 4: Some vital parameters shown on the mobiles and the related Json format.

software that is able to visualize the main values of the user physiology according to a standard XML/RDF ontology derived from the Json format shown in fig.4-right, and inspired by (Faro A.., 2003), (Heckmann D., 2005).

This allows the doctors to visualize at distance the current health status and the health history of the patient using any type of mobiles provided that the mobile is equipped with the proposed visualization software.

3 ENVIRONMENT MONITORING SYSTEM

Irregular respiratory rates or sudden changes in respiratory rate are a broad indicator of a major physiological instability; in many cases, the incorrect respiratory rate is one of the earliest indicators of this instability, e.g., (Ionescu et al., 2009), (Cnockaert L., 2008).

Therefore, our system can provide an early warning of hypoxemia and apnea. Also, monitoring blood pressure at home is important for many people, especially for the elderly patients who have high blood pressure. However, both respiratory rate and blood pressure should not always have the same average value for the elderly people living at home.

Indeed, they may change depending on the emotional status, on if the patient is walking, doing exercises or sleeping, and on the home environment conditions. Therefore, monitoring the main personal conditions is also important, e.g., emotional status could be identified recognizing modified facial features or reduced visual attention abilities, e.g., (Faro A., 2010), (Faro A., 2006), even in noisy contexts (Cannavò F., 2006), (Crisafi A., 2008). Also, it may be detected by measuring the perspiration activity, e.g., using galvanic sensors. Many sensors are available to monitor the physical activity and position, e.g., (Cooking-Hacks).

A complete analysis of the elderly overall status is outside the scope of the paper and it is for further study, whereas we are more interested in controlling the home environment conditions since they may influence greatly the blood pressure and the respiration status, e.g. warm temperature can increase blood pressure.

In many cases, a regulation by a simple automatic system may be enough to restore the right health status, e.g. the automated opening of a window or the starting of an air conditioner. For this reason the first check, carried out by our system, is the one of comparing the vital parameters with the surrounding environmental conditions.

Fig.5 shows a possible environment monitoring system controlled by an Arduino mega shield that takes information about light and temperature.

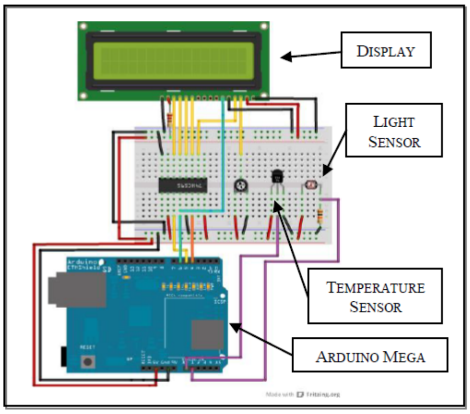


Figure 5: Environment Monitoring System.

This allows the system to control temperature and light of the rooms and if the patient blood pressure is high, to lower it by opening/obscuring a window and starting an air conditioner. Only after having observed that these actions are not successful, the system will carry out further actions: first, it will indicate to the patient, on his/her mobile, the nearest hospital, then it will inform the family members and the doctor about the patient health status, and finally it will send the alarm to the near hospital including information on the vital parameters of the patient.

4 USER MODEL ONTOLOGY

Fig.6 shows a simplified scheme of the general user model ontology (Heckmann D., 2005) that we propose to use to collect all the relevant data according to an open and interoperable data organization so that people can be aided in either normal or critical situation by cooperating intelligent agents resident on different computing devices, e.g., the user or family doctor mobile, the computing system located on the ambulance, or the server of the hospital.

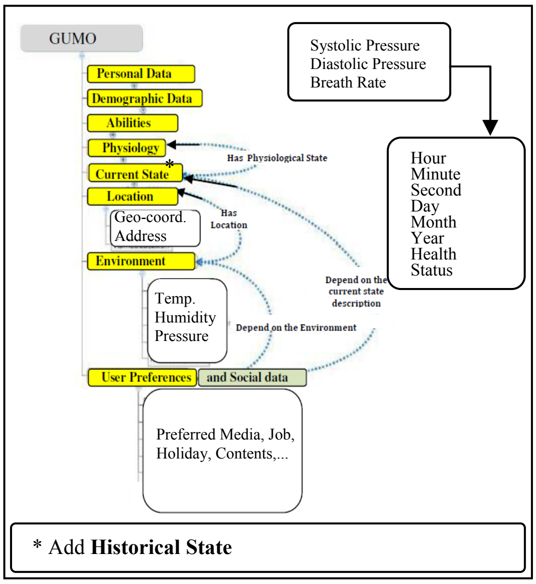


Figure 6: General User Model Ontology.

In such scheme, we point out how the data collected by our health monitoring system are useful to fill the sections related to physiology and environment. In addition, we propose to substitute the section current state by a section dealing with the current and historical state consisting of records featured by clock time and user status periodically added to the previous ones.

This allows the doctors to know the physiological data, e.g., the breath rate data with respect to the clock time and to the status of the people at this time. For example they may know the heart data in the period in which the people is suffering from anxiety. Of course, only a limited amount of the data should be available on line, e.g., the data featuring the last hour relevant to plan the best rescue in case of sudden critical user condition could be stored on the user mobile, whereas the previous data, more relevant for clinical purposes, should be stored in the personal computer available at the user home or at the hospital.

Fig.7 shows the XML/RDF format of the data available on the computing system extracted by a query issued by an intelligent software agent resident either on the local monitoring system or at distant ambulance or hospital servers to know the current health status of the elderly people and of the variable featuring the ambient.


```
<health>
  <blood>
    <syspress>135</syspress>
    <diaspress>85</diaspress>
  </blood>
  <breath>
    <rate>24</rate>
  </breath>
  <datetime>
    <hour>16</hour>
    <minute>54</minute>
    <second>47</second>
    <day>29</day>
    <month>6</month>
    <year>13</year>
  </datetime>
  <environment>
    <humidity>63</humidity>
    <temperature>24</temperature>
    <pressure>0.98</pressure>
    <luminosity>0.7</luminosity>
  </environment>
</health>
```


Figure 7: Personal and environment data in XML format.

A straightforward conversion of the XML/RDF format of the query response to OWL format is also available in our implementation to represent the data according to the web semantic standard format, i.e., according to the terminology and properties of well established ontology approved by W3C such as FOAF and SSN related to people and sensor ontology. A deeper discussion on this subject is for further study.

5 CONCLUDING REMARKS

The paper demonstrates the feasibility of reliable and flexible health monitoring systems aiming at controlling relevant health parameters by means of portable sensors of small dimensions, e.g., the ones needed to measure the blood pressure, the respiration rate and the glucose levels.

The reduced dimensions and the low cost of the selected Arduino shields and their communication features makes possible the monitoring at distance of the elderly people living at home using smart phones.

The RDF format chosen to store, on the memory of the Arduino GPRS and LAN shields, the data coming from the sensors allows the servers of authorized people to download and interpret the patient data with simple RDF based procedure.

The use of an agreed ontology such as GUMO is envisaged to open the data stored on the Arduino shield to the devices of remote authorized people. In particular, this will make possible to visualize the patient data on any remote mobile (of the family doctor or the user relatives) where they are displayed using simple procedure or integrated to other software able to carry out some deep diagnosis aimed at activating specific interventions.

We plan to use this system into the WiCity Project whose general aim is the one of supporting mobility, logistics and user health assistance in a smart city, e.g., (Costanzo A., 2012), (Faro A., 2011), (Faro A., 2008). A more powerful decision support system to improve people health status is planned according to the lines indicated in (V.L. Sauter, 2011), (Costanzo A., 2013).

REFERENCES

Huo H., et al.: An Elderly Health Care System Using Wireless Sensor Networks at Home, 2009 Third *International Conference on Sensor Technologies and Applications*, IEEE Computer Society, 2009.

Banzi M., Getting Started with Arduino, Make 2008.

Pino C., Costanzo A., Arduino based System for Monitoring the ECG Status and Improving Home Environment Conditions Int. *Conf. on Physiological Computing Systems*, PhyCS, Lisbon, 2014.

Heckmann D., et al., GUMO, the General User Model Ontology, LNCS, N.3538, Springer, 2005.

Islam M., et al., Development of a Noninvasive Continuous Blood Pressure Measurement and Monitoring System, IEEE/OSA/IAPR *Int. Conf. on Informatics, Electronics & Vision*, 2012.

Corlan M., Flash Platform Tooling: Flash Builder, Adobe, 2009.

Anciaux N., et al. Personal Data Management with Secure Hardware - The Advantage of Keeping your Data at Hand, IEEE *Proc on Mobile Data Management* (MDM), Milano, 2013.

Faro A., Giordano D., Musarra A., Ontology Based Mobility Information Systems. *Proc. of IEEE Systems, Men and Cybernetics SMC03, vol.3*, 4288-4293, 2003.

Ionescu et al., Mechanical Properties of the Respiratory System Derived From Morphologic Insight, IEEE *Transactions on Biomedical Engineering, Vol. 56*(4), 2009.

Cnockaert L., et al., A Method for the Analysis of Respiratory Sinus Arrhythmia Using Continuous Wavelet Transforms, IEEE *Transactions on Biomedical Engineering, Vol. 55*(5), 2008.

Faro A., Giordano D., Pino C., Spampinato C., Visual attention for implicit relevance feedback in a content based image retrieval, *Proc. ACM Symposium on Eye-Tracking Research and Applications*, ETRA 2010.

Faro A., Giordano D., Spampinato C., An automated tool for face recognition using visual attention and active shape models analysis, P*roc. 28th Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, EMBS'06, 2006.

Cannavò F., Nunnari G., Giordano D., Spampinato C., Variational Method for Image Denoising by Distributed Genetic Algorithms on GRID Environments. *Workshops on Enabling Technologies: Infrastructure for Collaborative Enterprises*, WETICE '06. 227-234, IEEE, 2006.

Crisafi A., Giordano D., Spampinato C., GRIPLAB 1.0: Grid Image Processing Laboratory for Distributed Machine Vision Applications. *Proc. Int. Workshop on Enabling Technologies: Infrastructure for Collaborative Enterprises*, WETICE '08. 188-191, IEEE, 2008.

Cooking-Hacks, Patient Position Sensor for e-Health Platform, http://www.cooking-hacks.com.

Costanzo A., Faro A., Giordano D., Venticinque M., Wi-City: A federated architecture of metropolitan databases to support mobile users in real time, IEEE *Proc. Int. Conf. on Computer & Information Science* (ICCIS), Vol.2, 586-591, 2012.

Faro A., Giordano D., Spampinato C., Integrating Location Tracking, Traffic Monitoring and Semantics in a Layered ITS Architecture. *Intelligent Transport Systems, vol.5* (3), 197-206, 2011.

Faro, A., Giordano, D., Spampinato C., Evaluation of the traffic parameters in a metropolitan area by fusing visual perceptions and CNN *processing of webcam images, IEEE Trans. on Neural Networks, Vol.19*(6), pp.1108-1129, 2008.

V. L. Sauter, DSSs for business intelligence, Wiley, 2011.

Costanzo A., Faro A., Giordano D., Wi-City: living, deciding and planning using mobiles in Intelligent Cities, *3rd International Conference on Pervasive and Embedded Computing and Communication Systems*, PECCS, Barcelona, INSTICC, 2013.