A SYSTEM FOR REMOTE MONITORING OF THE HUMAN BODY PARAMETERS

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Abstract*: We present an invention (pending patent number A 201100939) related to a system that monitors human body parameters, such as heart rate and blood pressure, and when they are out of the regular range, it transmits a remote warning signal along with the GPS coordinates of the patient to the special intervention services, or to the tutors, so that they can take action in the shortest time. The most important aspect of the system is its mobility, the patient being able to live her normal life, not having to stay in a fix perimeter, as it is the case for most monitoring equipments. The scope of the invention is the health of people, both individually and at the institutions involved in health insurance, such as clinics, hospitals, emergency services, rescue, SMURD, social settlements, etc.*

1. INTRODUCTION

A majority of older adults are challenged by chronic and acute illnesses and/or injuries. Hence, chronic disease management, post-acute care management, and safety monitoring are three important applications of remote patient monitoring (RPM) technologies for the older adult population, and not only. RPM technologies can help monitor the patients after surgical interventions or in case of chronic diseases. RPM technologies can also alert care givers and prompt intervention when a vulnerable older adult is injured or in harms way.

More than 70% of the strokes in the case of elders generate significant variations in heart rate or pulse, therefore it is important to monitor these human body parameters in order to prevent or to intervene in a critical period of time.

A. Related work

Worldwide, many other systems that monitor different parameters of human body are known, especially hospitals or other health institutions. Also, other ”home usage systems” are known, systems being in the reach of the patient, mostly outside the health institutions, systems that monitor different parameters of human body, especially blood pressure, the recorded value being revealed to the patient either by a traditional display or by a digital one. the disadvantage of this system is that patients should know the normal range of blood pressure values, to determine whether the recorded value is within the normal range or not.

Several systems for monitoring biological signals use radio waves and telephone lines. The disadvantages of these solutions are generated by their low performance, their complexity, allowing identification of the subject and the occurrence of an emergency situation, this information being sent to a third person rather to the one in question.

For example the monitoring and warning system related to vital physiological parameters of persons exposed to risk factors because their work is carried out under extreme conditions (in depth or height, in narrow spaces, extreme temperatures, thin or flawed atmosphere, etc.) [5] has the main disadvantages of requiring a multitude of devices: monitoring equipment, and some portable interfaces, including a tactical technique, all occupying a relatively large space and are operated by someone other than those monitored. also, another disadvantage is that this system addresses only to a certain category of people, not to everyone.

The system for monitoring biological signals presented by the patent [6] has the major disadvantage is that, although it can monitor a large number of subjects, it is only intended for medical offices, which are served by staff who have the human biological parameters.

The patent [7] refers to a detector of vital body functions in order to monitor pulse, blood pressure, etc. and transmission of measured values for display and storage on a daily communication terminal comprising a sensory way, communications equipment and an external GPS system. The disadvantages of this solution are: because of how it is designed, the system works continuously, transmits values continuously and thus consumes significant energy, and periodic maintenance of the system is required, also causing rapid wear of the component equipment.

2. ARCHITECTURE OF THE SYSTEM

The system comprises of two major parts (see figure 1): a sensory module (8) and a communication equipment (1), e.g. a smart phone.

The sensory module is composed of sensors (9) for pulse, heart rate, temperature etc., which sends the signal to an amplifier (10), which, in turn, sends the signal to a microcontroller (11). This is responsible for processing the information and decide whether there are significant variations of the signal, which are to be sent to the communication equipment. If there are significant variations, the data is transferred through a communication interface (12). Due to the microcontroller, the communications between the two modules, (8) and (1) are minimal, which leads to important energy savings.

The data sent by the sensory module (8) is received by the equipment (1) through a communication interface (2), similar to the interface (12). Then they are send further to the processor (6), which uses some complex algorithms for deciding if the values sensed by the sensor (9) are in normal ranges. If not, a message is shown on the display (7). Moreover, the information along with the geo-spatial coordinates collected by the GPS (5) are sent as vocal or written message (e.g. SMS, MMS) and over the Internet (as an email or by connecting to a server, through a client-server application).

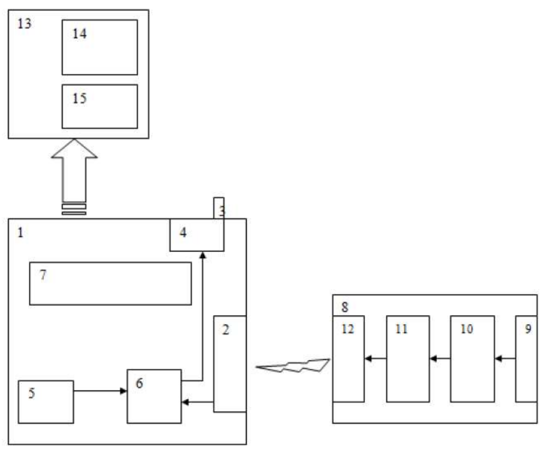

Fig. 1 - The architecture of the system

The application (13) shows on a map (14) the location of the surveyed person and by means of a special software module draws the optimal routes to her.

The sensory module (8) is like a bracelet or more like a wrist watch and contains the sensor (9), the operational amplifier (10), the microcontroller (11) and the communication interface (12). The sensors can be multiple, e.g. for pulse, heart rate, temperature etc. The most needed and useful ones are the for pulse and heart rate. The amplifier (10) is needed to increase the signal from the sensor (9) and send it to the microcontroller (11). The microcontroller can read the values and compare them with the regular ones, for each type of sensor. It is very important because it reduces the communication between module (8) and (1) significantly. As the data is read every 5 seconds, a (wireless) connection between the two modules would be established every 5 seconds. Such a connection requires much energy, that is why the microcontroller sends alerts to the communication module (1) only when needed.

The communication terminal (1) may be a smart phone, but not necessarily. It contains a (wireless) communication interface (2) similar with the interface (12) and may be a bluetooth module. The processor (6) controls the entire device (1) and receives data from the GPS (5). For any smartphone, the GPS (5) is embedded by default. The display (7) is used for the interface with the user. Module (4) is a GSM interface.

A. Activity diagram of the system

In order to make the worflow of the system explicit, we depicted in figure 2 the activity diagram. In the activity diagram shown in figure 2, the shapes represent:

- rectangles represent activities;
- rounded rectangles represent composed activities;
- bars represent the start (split) or end (join) of concurrent activities;
- diamonds represent decisions;
- an oval represents the start (initial state), respectively the stop (final state) of the workflow.

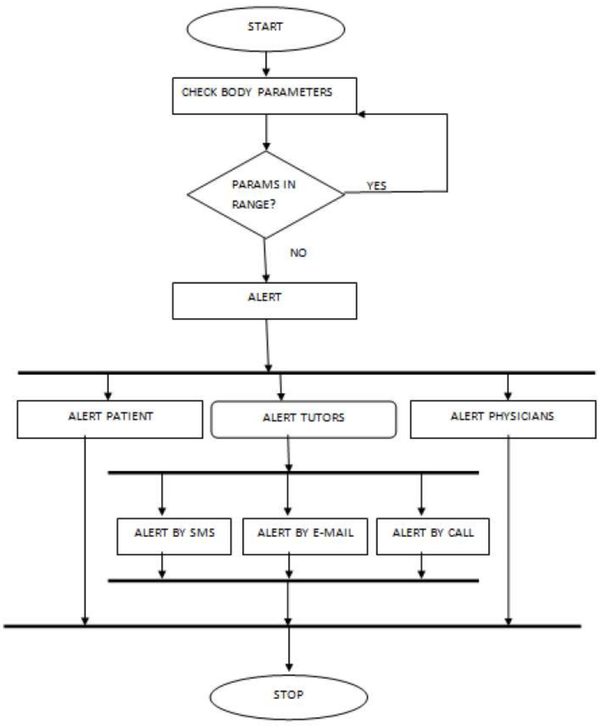

Fig. 2 - The activity diagram of the system

Arrows run from the start towards the end and represent the order in which activities happen. Hence they can be regarded as a form of flowchart. Typical flowchart techniques lack constructs for expressing concurrency. However, the join and split symbols in activity diagrams only resolve this for simple cases; the meaning of the model is not clear when they are arbitrarily combined with decisions or loops.

The diagram shows that the system never stops monitoring the body parameters (such as pulse and heart rate). If the values are out of normal ranges, an alert along with the GPS coordinates are emitted towards:

- the patient herself (on the display or by audio signal);
- the tutors, by e-mail, SMS or call;
- the supervising physicians (e.g. emergency room or ambulance service).

B. The sequence diagram of the system

To illustrate better the usage of the system, figure 3 depicts the sequence diagram. The processes and message involved among the modules are very simple, yet must be very robust because they are about the health of a human being.

As a matter of fact, between the two main modules there are only two types of messages: for initial pairing and when there are alerts regarding the values read by the sensor. We want to emphasize that the communication between the two modules is reduced as much as possible in order to save energy and the whole system must be very robust and it was designed having this in mind.

3. THE SERVER SIDE

The server-side software component is able to display the coordinates of the monitored patient on a map and route an ambulance to there. For a significant number of surveyed patients, the application is able to each medical team to more patients, if needed. That is done using an algorithm similar to the one presented by Pop and Matei in [9]. They describe a genetic algorithm for solving the generalized traveling salesman problem (GTSP). This problem is a generalization of finding a minimum cost Hamiltonian circuit or cycle of a given graph by considering instead of nodes node sets (clusters) and asking for finding a minimum cost Hamiltonian circuit or cycle which includes exactly one node from each cluster. This problem is called the generalized traveling salesman problem (GTSP) and it was introduced independently by Henry-Labordere [2], Srivastava et al. [14] and Saskena [12].

Further on we will present the algorithm.

A. Genetic Representation

An individual is represented as a pair (C,N), where $C=(V_1,V_2,\ldots,V_m)$ represents the sequence of clusters, described as Hamiltonian cycles. $N=(N_1,N_2,\ldots,N_m)$ represents the set of nodes selected from each cluster, meaning that the node N_k is the node selected from the cluster V_k. The individual $\mathrm{I}=(\mathrm{C},\mathrm{N})$, with $C=(1,5,3,4,2)$ and $\mathrm{N}=(10,23,31,44,52)$ represents the tour which passes the clusters in the following order:

$$1\text{-}5\text{-}3\text{-}4\text{-}2\text{-}1$$

and the nodes as follows:

$$10\text{-}52\text{-}31\text{-}44\text{-}23\text{-}10$$

B. Initial population

The construction of the initial population is of great importance to the performance of GA, since it contains most of the material the final best solution is made of.

In our algorithm the initial population is generated separately for the set of clusters, respectively for the set of nodes selected from the clusters. Each cluster V_k is generated randomly from the set of the m m clusters. The set of nodes N_1 selected from the clusters is generated based on the Monte Carlo method. The first element N_1 is chosen randomly from the set of the nodes belonging to the cluster V_1. Each further node N_k, with $k\in\{2,\ldots,m\}$, is selected randomly inverse proportionally with the distance (cost) from its predecessor node: $d_k=c(N_{k-1},N_k)$. The probability for each node to be selected is

$$p_i=\frac{d(N_i,N_k)}{D},\text{ where } D=\sum_{k=1}^{|V_i|}d_k \quad (1)$$

It is obvious that the probability for a node to be chosen increased as the distance to the node N_k decreases. We define a summing probability:

$$D=\sum_{i=1}^{|V_i|}p_i \quad (2)$$

A random number $r\in[0,1]$ is chosen, which gives the node to be selected as being i which holds $r\in[q_i,q_{i+1})$.

Based on computational experiments we observed that this method assures an initial population with a fitness with 20% better than a population generated entirely randomly.

C. The fitness value

Every solution has a fitness value assigned to it, which measures its quality. In our case the, the fitness value of a feasible solution (generalized Hamiltonian tour) of the GTSP is given by the total cost of the edges selected in the Hamiltonian tour i.e. the objective function of the integer programming model presented in the previous section. The aim is to find the generalized Hamiltonian tour with minimum cost.

D. Genetic operators

1) Crossover: Two parents are selected from the population by the binary tournament method, i.e. the individuals are chosen from the population at random.

Offspring are produced from two parent solutions using the following crossover procedure described by Matei in [3]: it creates offspring which preserve the order and position of symbols in a subsequence of one parent while preserving the relative order of the remaining symbols from the other parent. It is implemented by selecting a random cut point. The crossover operator for the set of nodes N is straightforward.

The recombination for the route C require some further explanations. First, the symbols before the cut points copied from the first parent into the offspring. Then, starting just after the cut-point, the symbols are copied from the second parent into the offspring, omitting any symbols that were copied from the first parent. The second offspring is produced by swapping round the parents and then using the same procedure.

Next we present the application of the proposed crossover for the cluster route C. We assume two well-structured parents chosen randomly, with the cutting point between 2 and 3:

$$C_1 = 1 \quad 4 \quad | \quad 2 \quad 3 \quad 5$$
$$C_2 = 2 \quad 1 \quad | \quad 5 \quad 4 \quad 3$$

The sequences before the cutting-point is copied into the two offspring:

$$O_1 = 1 \quad 4 \quad | \quad x \quad x \quad x$$
$$O_2 = 2 \quad 1 \quad | \quad x \quad x \quad x$$

The nodes of the parent C_1 are copied into the offspring O_2 if O_2 does not contain clusters in the as the nodes of C_1. Note the the cluster 2 is already represented in O_2. And the same holds for O_1 and C_2:

$$O_1 = 1 \quad 4 \quad | \quad 5 \quad x \quad 3$$
$$O_2 = 2 \quad 1 \quad | \quad x \quad 3 \quad 5$$

The already existing clusters are replaced by their correspondents from the other parent:

$$O_1 = 1 \quad 4 \quad | \quad 5 \quad 2 \quad 3$$
$$O_2 = 2 \quad 1 \quad | \quad 4 \quad 3 \quad 5$$

2)Mutation: We use in our GA two random mutation operators: the first one (intra-route mutation) selects randomly a cluster to be modified and replaces its current node by another one randomly selected from the same cluster and the second one (inter-route mutation) is a swap operator, it picks two random locations in the solution vector and swaps their values. Similar mutation operators are reported by Pop et al. in [8].

The developed GA uses the steady-state approach, in which eligible offspring enter the population as soon as they are produced, with inferior individuals being removed at the same time, so that the size of the population remains constant.

3) Selection: The selection process is deterministic. The first selection is $(\mu+\lambda)$, where μ parents produce λ offspring. The new population of $(\mu+\lambda)$ is reduced again to μ individuals by a selection based of the "survival of the fittest" principle. In other words, parents survive until they are suppressed by better offspring. It might be possible for very well adapted individuals to survive forever. This feature yields some deficiencies of the method [1]:

1) In problems with optimum moving over time, a $(\mu+\lambda)$ selection may get stuck at an outdated good location if the internal parameter setting becomes unsuitable to jump to the new field of possible improvements.
2) The same happens if the measurement of the fitness or the adjustment of the object variables are subject to noise, e.g. in experimental settings.

In order to avoid effects, Schwefel investigated the properties of $(\mu+\lambda)$, selection, where μ parent produce $\lambda(\lambda>\mu)$ and only the offspring undergo selection. In other words, the lifetime of every individual is limited to only one generation.

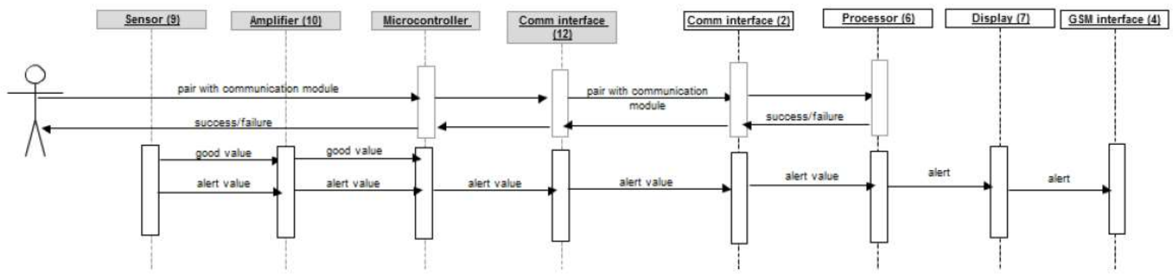

Fig. 3 - The sequence diagram of the system

The limited life span allows forgetting the inappropriate internal parameter settings ([11]). This may lead to short periods of recession, but it avoids long stagnation phases due to unadapted strategy parameters [13]. The $(\mu+\lambda)$ and (μ,λ) selection fit into the same formal framework with the only difference being the limited life time of individuals in (μ,λ) method.

E.Genetic parameters

The genetic parameters are very important for the success of a GA, equally important as the other aspects, such as the representation of the individuals, the initial population and the genetic operators. The most important parameters are:

- the population size μ has been set to 5 times the number of clusters. This turned out to be the best number of individuals in a generation.
- the intermediate population size λ was chosen twice the size of the population: $\lambda = 2 \cdot \mu$.
- mutation probability was set at 5%.

4. DIFFERENCES BETWEEN OUR SYSTEM AND ITS MAIN COMPETITOR

A very similar invention is the one described by the patent DE 10029065 [7], depicted in figure 4. The transmission unit (3) transmits measured values from a sensor to a communication terminal (1). The communication terminal is designed to display (8) and/or store (12) the measured values. A time measuring device (13) measures the time during the detection of the measured values. A computer unit (6) may output signals to a telephone number, e-mail address or output a text message to a telephone number, or output an audible, visual or vibration signal.

However there are several differences between the two. The first one consists of the existence of the microcontroller (11) in the sensory module. It can compare the values sensed by the sensor (9) with the normal ones and sends them to the communication equipment (1) only if there are significant variations. This way, an important energy is saved, especially in the case of wireless communication.

A second difference is that in our system, the GPS (5) is embedded into the communication equipment (1) and it is not external, as in the case of patent DE 10029065. So that, our model has 2 important modules (sensory and communication), whereas the one in the competitor patent has a third one - the GPS.

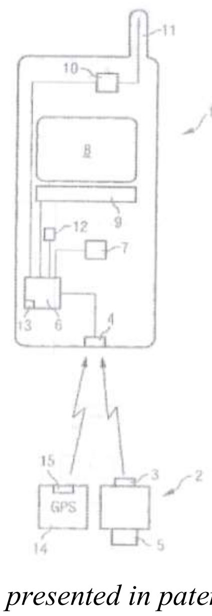

Fig. 4 - The system presented in patent DE 10029065[7]

4. CONCLUSION

The article presents a device, subject of the patent A 201100939, which monitors a patient's body parameters, such as pulse, heart rate and temperature and alerts when their values are out of regular ranges. The main advantages of the system are:

- the system is mobile, so that the patient can live her normal life, without having to stay all the time in a limited area, such as home, hospital etc.;
- the alerts emitted by the system contain also the coordinates of the patient;
- the communication between the sensory module and the communication module is done only when needed, not all the time;
- the communication module interfaces with a server side application, used by physicians, which can send a rescue team.
- low cost of the equipment;
- low cost of the maintenance.

A. Future work

Future developments of the solution presented in this article are possible, regarding both hardware and software functionalities. The usage of the device may be extended for monitoring the patient:

- in the acute phases of illnesses;
- for diagnosing specific illnesses;
- in post-operator stages.

In all these cases, specific devices are used, such as Holters [4], which act like portable EKGs, or electrocardiograms. An electrocardiogram interprets a heart's electrical activity over time. Patients commonly wear a Holter for a period of 24 hours, but if symptoms remain too intermittent to diagnose, doctors may require patients to wear the device for a longer period. The Holter records EKG readings on strips on a tape. After the Holter is removed, a physician can review the EKG results to analyze the heart rhythms. Therefore it would be very useful to connect the holter to our system and send the data real-time. Doing so, is something goes wrong with the patient, the physicians are informed and can intervene immediately.

Another improvement regards the possibility of the serverside application to take into account the capacities and facilities of the ambulances. In this cases, more complex algorithms are to be used, such as the ones presented in [8], [10].

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REFERENCES

[1] T. Back, F. Hoffmeister and H. Schwefel, *A survey of evolution strategies,* in Proc. of the 4th International Conference on Genetic Algorithms, San Diego, CA, July, 1991, Morgan Kaufman.

[2] Henry-Labordere, *The record balancing problem: A dynamic programming solution of a generalized traveling salesman problem*, RAIRO Operations Research, B2, pp. 43-49, 1969.

[3] O. Matei, *Evolutionary Computation: Principles and Practices,* Risoprint, 2008.

[4] Arthur J. Moss, *Noninvasive electrocardiology: clinical aspects of Holter monitoring,* Springer, 2000.

[5] Patent RO 122960, *Sistem de monitorizare, teletransmisie si avertizare privind parametrii fiziologici vitali ai unor persoane expuse la factori de risc prin aceea ca activitatea lor se desfasoara in conditii extreme.*

[6] Patent RO 112575, *Sistem de teletransmisie si monitorizare a semnalelor biologice.*

[7] Patent DE 10029065, *Body function detector for monitoring pulse, blood pressure, etc., transmits measured values for display and storage on everyday communications terminal.*

[8] P.C. Pop, O. Matei, C. Pop Sitar and C. Chira, *A genetic algorithm for solving the generalized vehicle routing problem*, in Proc. of HAIS 2010,Part II, Editors E.S. Corchado Rodriguez et al., Lecture Notes in Artificial Intelligence, Springer, Vol. 6077, pp. 119-126, 2010.

[9] P.C. Pop, O. Matei and C. Sabo, *A New Approach for Solving the Generalized Traveling Salesman Problem,* in Proc. of HM 2010, Editors M.J. Blesa et al., Lecture Notes in Computer Science, Springer, Vol. 6373, pp. 62-72, 2010.

[10] P.C. Pop, O. Matei and H. Valean, *An Efficient Soft Computing Approach to the Generalized Vehicle Routing Problem*, Advances in Intelligent and Soft Computing, Springer, Vol. 87, pp. 281-289, 2011.

[11] Pop, Petrica C., and Oliviu Matei. "*An improved heuristic for the bandwidth minimization based on genetic programming*." *Hybrid Artificial Intelligent Systems*. Springer Berlin Heidelberg, 2011. 67-74.

[12] J. P. Saskena, *Mathematical model of scheduling clients through welfare agencies,* Journal of the Canadian Operational Research Society, Vol. 8, pp. 185-200, 1970.

[13] H.P. Schwefel, *Collective phenomena in evolutionary systems,* in Proc. of 31st Annual Meetting of the International Society for General System Research, pp. 1025-1033, 1987.

[14] Srivastava, S. S. S. Kumar, R. C. Garg, and P. Sen, *Generalized traveling salesman problem through n sets of nodes,* CORS Journal, Vol. 7, pp. 97-101, 1969.