Smart House Automation System for the Elderly and the Disabled

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ABSTRACT

To improve the quality of life for the elderly and disabled whose number keeps increasing in all industrialized countries, a smart multisensor system based on advanced telecommunication and information technology has been developed. It is designed to monitor these people so as to bring them more security and safety without disturbing their life. The living habits and behaviour of the elderly have thus been recorded with multisensor system. To be able to learn the habits of this group of people, Artificial Neural Networks (ANNs) are used. Thus any behavioural change can be diagnosed. The multisensor system along with the ANN methodology used for learning and some system functionalities are described. For one functionality, the results of habits learning are equally given.

I. INTRODUCTION

In all industrialized and developed countries, the progress of Medecine has increased life expectations and caused a decline in the birth rate, leading to a greater proportion of elderly and disabled people in the population. Thus population ageing requires on the part of society that it fully addresses the expectations and needs of the elderly in terms of better living, and more security, comfort and communications. The use of "Assistive Technology" allows two types of assistance to be extended to these people to enhance the quality of their lives. Indeed, active support devices like auditory aids compensating for a hearing deficiency can be employed or integrated systems and services allowing the users' social integration to be preserved or restored can equally be developed with the view of helping them in their daily life. In this context, we have developed an intelligent house automation system capable of monitoring the elderly and the disabled so as to enable them to live independently. This system relies on the ultimate developments in the field of Artificial Intelligence notably ANNs, Expert Systems, multisensing fusion of data, smart processors as well as a thorough analysis of the real needs and wishes of the end users and the acceptance of the system proposed. The aim is to follow the persons concerned be they disabled or old, without disturbing their daily tasks by placing a number of sensors in their home or flat to sense any going in or out, to measure light, and temperature and the amount of power consumed, etc ... These devices are connected to a computer allowing identification of daily habits by multisensing fusion of data. Thus habits can be learned and the right decisions made in case a major discrepancy occurs relative to the habits learned.

In this paper, Section II is concerned with the architecture of a multisensor system in the course of being installed in an institution for the elderly. The principle and methodology used for learning the habits are given in Section III. The various functionalities of the system (presence/absence, comfort, mobility, etc...) are presented in Section IV. Lastly Section V gives some results on the functionality of the presence/absence (learning the time table). Section VI gives the conclusion.

II. ARCHITECTURE OF THE SMART SYSTEM

The system is currently being installed in an institution for the elderly and the disabled. Thus twelve rooms have been connected to the system (see Fig. 1) :

i) In each room, an array of sensors is designed to collect the information reflecting the behaviour of the elderly and disabled person. These sensors are straightforward, 12 V or 24 V devices (all or nothing) equipped with dry or analog contacts connected to digital or analog input modules :

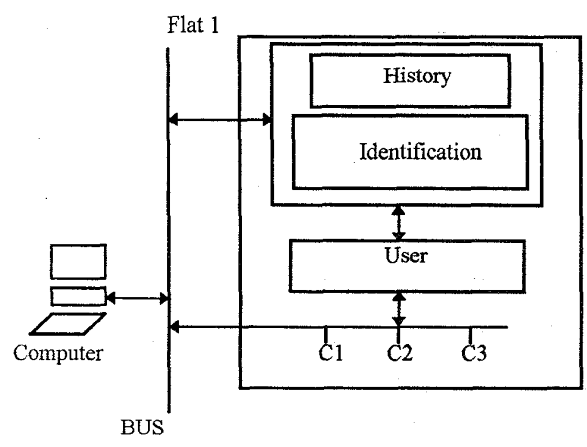

Fig. 1. Architecture of the System
C1, C2, C3 = sensors

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- 3 magnetic contact sensors are housed in the gates and protude on the window. When opening has been detected, the contact is "1" and "0" in the opposite case (closing) ;
- 5 active (IR) detectors have been placed on the external gate mount allowing estimation of size and determination of whether the person is entering or leaving the room. These devices have been laid out at 1m50, 1m60 and 1m70 and one against the wall just behind the entrance/exit door. They consist of an emitter (IR barrier) and a receptor ;
- 6 passive (IR) detectors are employed to detect motion. These have been placed on the ceiling at a height of 2m92 and form a circle on the floor having a diameter of about 2m20. These detectors respond to any heat variations and hence to any individual's movements ;
- 2 temperature probes (located respectively indoors and outdoors) are connected to two relays delivering a voltage between 0 and 10 V which is proportional to temperature. Thus the temperature limit can be controlled ;
- 2 press buttons replace the conventional switches. The information thus collected permits to determine whether lighting is on or not ;
- an overintensity switch is equally employed to know whether the TV set is on. Thus the overintensity threshold can be controlled.

ii) A computerized monitoring station made up of a PC computer, a screen and keyboard are used. This PC can store the learning data base containing the habits of each old person being monitored. This learning data base is also referred to as history. The PC computer can also be employed to store any information about the user. This is what we call the identification in Fig. 1. (i.e. the civil status, etc ...). The computer uses all the pieces of software that allow learning of the habits and daily decision making and diagnosis. Lastly, this PC also serves as a dialog or interface box for monitoring personnel between them and the multisensor system.

iii) A Binary Unit System (BUS) serves as a link between the PC and the sensors.

III. PRINCIPLE AND METHODOLOGY

It has been assumed that the elderly lives alone in his/her bedroom with repetitive and identifiable habits that form the basis of the diagnosis in case a discrepancy is detected relative to his/her usual behaviour. ANNs [1] are therefore used for learning the habits, depending on a number of parameters. Each ANN is in itself a dense interconnection between the formal neurons which constitute the information processing units having currently nonlinear transfer functions and act in parallel. One of the advantages of the networks is that they can be used as "black boxes". They can model any system without a priori knowledge of its internal function. It suffices to have a set of Input/Output vectors from the experiment and is characteristic of the task to be modelled. This set of data constitutes the learning data base. Learning is the procedure that consists of finding and adapting the parameters of the ANNs in such a way that the process to be modelled is as much approximated as possible. The network is fully defined by type of the formal neurons, the architecture of the connections and the learning rule. We use neurons that activate as a function of the input data and transmit this activation to the other neurons to which output is connected. It performs three functions: an input function which is the

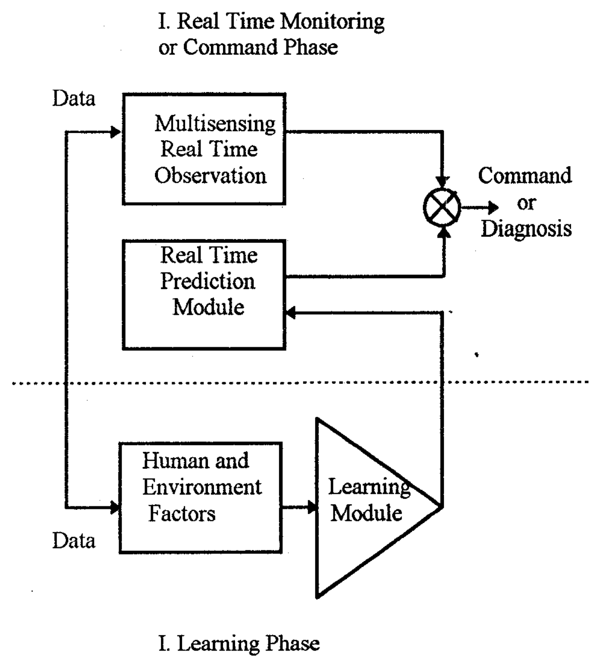

Fig. 2. Principle Used

weighted sum of the input data and the weights of the network, an activation function which is a sigmoid, the output function used being a linear function. As an architecture we chose the one in which the neurons are arranged in layers and where the activations propagate from layers to layers up to the output layer with only one hidden layer. It is the backpropagation algorithm of gradient which is employed as a learning rule to obtain a gradient descent [2] of the sum of errors of the network outputs and to find the parameters of the ANN. Once the ANN has been built up, the system operated daily furnishes an output to an input which may not be part of the set of data used for learning. Given the data recorded in real time, the multisensor system provides the state of the situation. Comparison with the prediction made by the learning software allows diagnosis of a normal or abnormal situation.

The principle used is summarized in Fig. 2. Three phases are planned in the implementation of the system :
- learning the habits of the elderly with the designer ;
- testing with an analysis of the wrong alarms (if any) ;
- daily handling as such.

IV. THE FUNCTIONALITIES OF THE SMART MONITORING SYSTEM

The system consists of several functionalities (see Fig. 3.) : presence/absence, location, mobility, comfort.

IV. 1. Presence/Absence Function or Time Table Learning

It is assumed the elderly has a fairly regular time table in his flat. Once the multisensor system has been turned on, the data

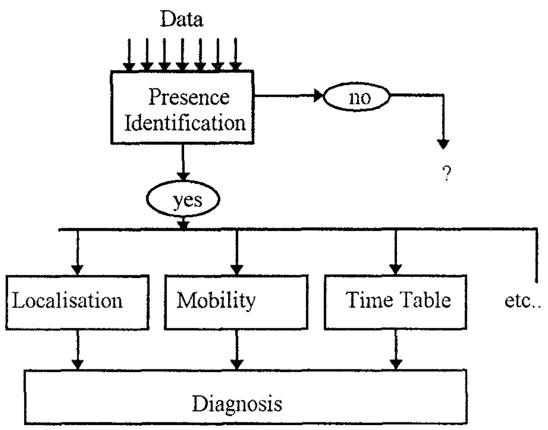

Fig. 3. Flow Chart of the Fonctionalities of the Smart System

data from the sensors start to be recorded. A history of all the enterings and leavings can be obtained along with their time and frequency. Identification of the person entering the flat is based on this. As soon as a person enters the room, the history should enable us to detect whether he is the occupant or not. The "size" sensors mounted at the flat entrance provide an additional piece of information for identification purposes. The visits to the elderly are first considered as disturbing factors like noise.

The data recorded is made up of a succession of presences/absences over a week, thus forming the learning data base. The latter gives the time table. An ANN is built up so as to learn it. For example an input/output data vector is equal to (20 mn, 30 mn, 50 mn, 40 mn ; 10mn), the first number corresponds to the presence of 20 minutes in the flat, the second to the absence of 30 mn and so on as so forth, the network providing as output a presence of 10 mn. During the generalisation phase or daily use, the network yields the output for an input data vector. The sensor system will therefore provide in real time the presence or absence of the occupant. In case of discrepancy between the prediction given by the ANN and the response of the multisensor system, the alarm will be triggered off.

IV. 2. Location Function

This function is more complex and yields the time table of the elderly no longer as a succession of presences/absences, but in the form of a time table with activity cycles, providing the multisensor system has located the occupant precisely and determined his activity like getting up, having a wash, watching TV, having a meal, etc... with the duration of such activities. According to the same principle the system learns these data. During the generalisation phase or daily use, an output is given for an input vector data. An alarm triggers out if a discrepancy between the output of the ANN and the real time response of the multisensor system is detected relative to the usual behaviour.

IV. 3. Mobility Function

This function measures at any moment in time the mobility of an old person in his bedroom as a number of kilometers done since a time origin and for a given duration. Like in the other functions, learning the habits in terms of mobility is performed by the ANN.

IV. 4. Comfort Function

This function allows managing the power needed to maintain the user's comfort [3]. The system performs an optimization of the power used for heating without intervention of the user based on :

- the learning of the user's habits (comfort temperature) ;
- the learning of the usual temperatures in the room according to the environmental parameters ;
- the learning of the user's time table (presence/absence in his room).

The user's habits in terms of the temperature of a room where the elderly lives are stored using statistics or an ANN. The learning of the usual room temperature depending on the different environmental conditions (outside temperature, sunshine, inside temperature of the adjoining rooms, etc...) and on the amount of power consumed by the heating element is processed by building the ANN. At daily use, a piece of software compares predicted comfort temperature of the user and the effective temperature of the room. Then using the function presence/absence (cf paragraphe IV 1), it searches if the person is present or absent from the room, the turning on or off of the heating element being anticipated before the arrival or departure of the user or is simply maintained and adapted to the temperature desired if the user is present. No manual programming for the heating is needed.

V. RESULTS

The learning base used is a set of combinations between a succession of past times denoting the presences/absences (inputs) and the time immediately following (output), over a period of one week. This learning base is then normed (using values between 0 and 1). The study has focused on the identification of the neural networks capable of learning "by heart" this learning base from initial weights selected at random between -0.5 and +0.5 : this is an essential first step in the learning of habits and their variations. In addition this learning has been done with structures made up of three to four layers exibiting four to five neurons in the input layer, one neuron in the output layer and from 3 to 26 neurons in the hidden layers. The presented results (in the form of convergence rates) are statistics computed from the results found for each learning following random selection of the initial weights, that is a mean value over 200 to 300 learnings.

Thus if the convergence rate reaches 90 percent, it means that a neural network whose initial weights are randomly selected must have 9 chances out of 10 of providing the right time table.

The results obtained are summarized in Fig. 4.

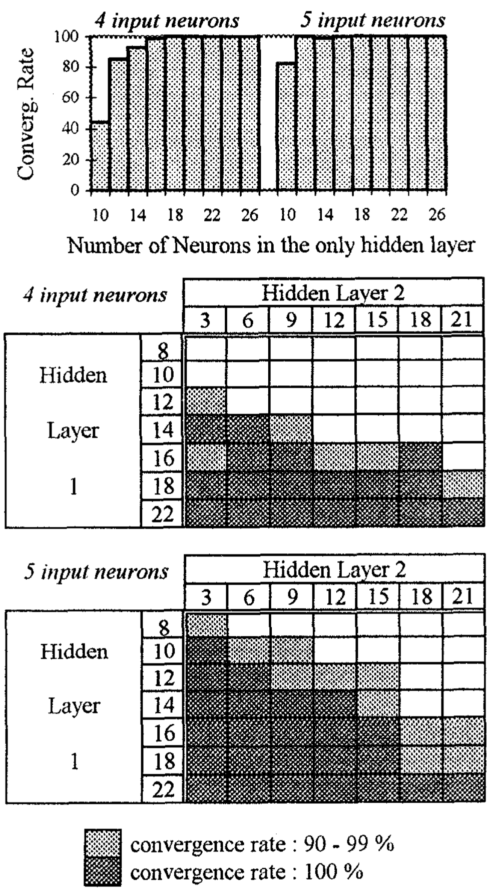

Fig. 4. Convergence Rates

The three-layer networks are therefore 100 % reliable from 14 neurons in the hidden layer. The same also holds for certain four-layer structures.

The latter structures are then compared. The comparison criterion referred to as the computational number, is the number of times a weight from the whole network is modified. Within a multiplying factor, it is approximately the computation time needed for learning. The results found are summarized in Fig. 5.
Two comparisons can be made, namely :
- according to the number of hidden layers : generally, three hidden layers require less computations than four ;
- between the number of neurons in the input layer : similarly, 5 neurons seem preferable to 4.
This trends is confirmed on the other learning bases.

Finally, it appears that the time tables are learned in a reliable manner by the three-layer networks including five neurons in the input layer, from 18 to 26 in the hidden layer and one in the output layer.

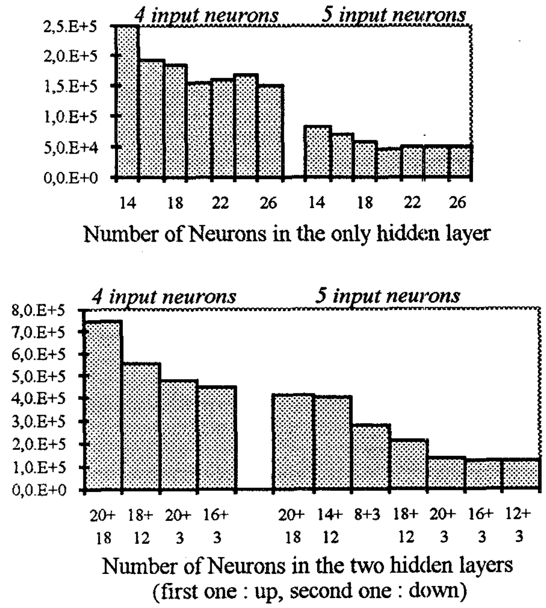

Fig. 5. Computational Numbers

VI. CONCLUSION

In this paper we have developed a smart house automation system for monitoring the elderly and the disabled so as to help them live independently while respecting their autonomy. The principle used is original. It consists of learning the habits of the old person and relies on this, to arrive at a diagnosis in case of a change in his behaviour. This system operates on its own and requires no human intervention. It could be used by the elderly who are not always prepared to handle complex technical systems. The system is being installed. The next step will consist of studying the identification part of the occupant on site and testing the different functionalities with the users.

VII. REFERENCES

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