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Title Page

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A Neuro-Fuzzy Embedded Agent Based Approach for Abnormal Behaviour Detection in Intelligent Health Care Environments

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Introduction

This paper presents a novel embedded agent mechanism based on a neuro-fuzzy approach which is able to recognize activities inside an environment in an on-line mode. Its ultimate goal will be to learn, discriminate and react to personal behaviours and signal departures from the normal behaviour that are significant for its application on the health care environments. This work aims to realise the vision of ambient intelligence in health care environments. The concept of ambient intelligence refers to a world in which people are surrounded and empowered with digital environments that are sensitive and responsive to their needs. In our system we will combine the use of unobtrusive sensors and effectors with intelligent embedded-agents. Previous work [] have shown that is feasible to build such systems although our work will differ in that as we seek to employ techniques that are able to detect more subtle deteriorations in a persons physical ability, that might signal the onset of conditions that would benefit from early diagnosis.

State of the art

There are two main approaches employed in human behaviour recognition systems: statistical and connectionist (relying basically in the use of neural networks). The former approach is usually combined with expert analysis in order to identify correlations between sensors and activities.

For example, there has been work in developing naïve Bayes classifier for activity labelling by indirect observation of the sensor activation signals and a context-aware experience sampling tool (ESM) was implemented on a PDA []. In this work, dependence between activities and object-involvement has been modelled using Bayesian belief net representations []. Although some Bayes-based approaches have proved to be good classifiers, some of them can't be applied to real domains with online learning because they can be computationally expensive.

In addition, many different types of Markov processes have been tried []. However, Hidden Markov Models have the disadvantage of making very complex networks and their learning algorithms have proved difficult to apply to problems involving numerous low-level sensors.

The connectionist (mainly neural networks) approach has been used previously. One of the most important works in the area is the Neural Network House []. It is mainly focused on the intelligent control systems in a house. An interesting difference is that the objective function seeks to balance some occupant discomfort against energy efficiency, which differs to approaches that seek to place the user's requests as the highest priority.

Whilst neural networks have shown themselves capable of providing good solutions to the sort of problem domain we are addressing, it has been often argued that they suffer from the incomprehensibility of the decision making process (being essentially "black boxes").

It also has been stated [] that adapting neural networks to the continuous changes in an intelligent space might require retraining the whole network which can be a computationally expensive process especially in cases that require on-line adaptation.

However, some connectionist approaches have been developed to overcame both the Neural Networks' drawbacks of the incomprehensibility of the decision making process and the difficult process of adapting them to continuous changes in the environment, most notably Neuro-Fuzzy systems. This will be the focus of the work described in this paper.

Research

Two of the main major concerns related to intelligent health care environments are methods of recognizing and adverting medical crisis, and the lack of proper agent architecture able to cope with the challenges of more demanding scenarios[].

An agent capable of learning can be employed to determine a normal set of personal behaviours and then detect deviations associated with the onset of illness or physical disability; this is referred to as "abnormality detection".

Abnormalities in behaviour can be observed in diseases such as Alzheimer and dementia. For example sleeping disorders are common in people with dementia, and the sleep/wake rhythm in Alzheimer's disease is extremely disturbed. One of the warning signs of Alzheimer's disease is a difficulty to perform familiar tasks[]. People with dementia often find it hard to complete everyday tasks. A person with Alzheimer's may not know the steps for preparing a meal, using a household appliance, or participating in a lifelong hobby or he/she might cook a meal but forget to serve it [].

Previous work from other fields had shown that neural networks can be used with great success to detect abnormalities in fields like security monitoring, engines and power plants []. However, for this approach to be applied to detect abnormal human behaviours in intelligent environments, it must be extended and modified. Using a neuro-fuzzy system helps to overcome the fact that it is very difficult to interpret the decision making of a neural network, nevertheless, the current neuro-fuzzy systems have the problem that they need to retrain such a system every time new environmental information is presented or new inputs or outputs are added.

To overcome those drawbacks, we propose the use of an Evolving Connectionist System (ECOS) []. By using this approach, we have built an on-line system, able to work in real-time and to evolve and adapt itself to the inhabitant's behaviours and later spot abnormal behaviours by comparing the learnt activities with the current activities inside the environment.

Our system is able to generate understandable rules and to extract/insert fuzzy rules. This gives the possibility to interpret the relationships between the sensors and the activities as well as the ability to add specific information to the system that could be useful for the detection of unusual or abnormal activities in a care environment. Also, by modifying the evolving fuzzy-neural network both supervised an unsupervised learning modes can be used, and in that way we can test our system using supervised learning before exploring the use the unsupervised learning (the later approach would be a major contribution necessary for a truly non-obtrusive system, not relying on explicit interaction with the inhabitant).

We have used a novel supervised ECOS system shown in Figure (1).

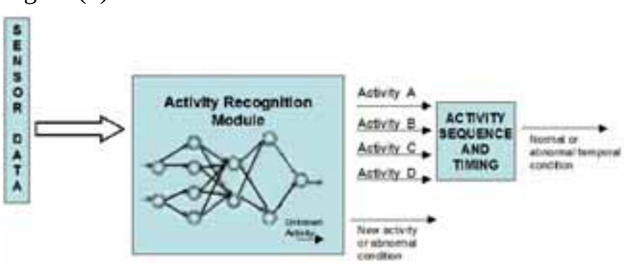

Figure 1 System Architecture

The proposed system was implemented inside the iDorm, a pervasive computing testbed based in the University of Essex []. The iDorm looks like a typical study/bedroom environment and it comprises of a large number of embedded sensors and actuators. Although we are currently testing our system on a small environment, we plan to roll this experimentation out to a full sized domestic flat called the iFlat which is under construction at the University of Essex (funded by UK SRIF). This will be done in order to test the system under conditions that are similar to the ones found on the environments it is meant to be applied (a home environment modified to provide health care).

The abnormality detecting agent is programmed using the Java language and built on top of the low level UP&P control architecture, enabling it to communicate with all the UP&P sensors and devices in the iDorm. Although, for greater experimental convenience, the current agent is now operating from a standard PC, it is possible for the agent to be embedded into internet devices due to the cross platform versatility of the Java programming language. By embedding the agent into such devices and integrating wireless communications, this will lead to the kind of pervasive transparent infrastructure characteristic of an ambient intelligent system.

Results

Our proposed technique has been tested using the data collected by 18 sensors (both environmental and furniture based) over a period of 4 days on an attempt to recognize 7 different activities inside the environment. To assist this process, during the experiments, the user has been asked to describe the action he/she was performing via a simple user interface. The agent monitors the user's actions over a period of time in the environment. Whenever the user changes the state of the environment, the agent records a 'snapshot' of the current inputs (sensor states).

A predefined number (5) of triangular membership functions have been used, having a five layer network with 18 inputs and 7 outputs.

Our system has been compared with other supervised off-line techniques to test its performance (using tenfold cross validation over 471 instances). 2 tests were made using a MLP, the first training it for 500 epochs and the second one training it only for 1 epoch. Our system performed better than a Bayes classifier, clearly outperformed the MLP trained for 1 epoch and showed a comparable performance against the MLP trained for 500 epochs. It is worth mentioning that our system was trained only using one-pass learning. Moreover, our system was able to deliver human readable rules.

In the full version of the paper we will introduce the investigation the parameters and thresholds that we propose for determining unusual or abnormal activities, as well as the way the temporal relationships between the activities can be represented.

Conclusions

The results show that our ECOS approach is suitable to be embedded on an agent, and is able to learn in an on-line (one pass) and incremental way, adapting itself to both the human behaviours and different configurations of the sensory set, and capable to generate human readable rules.