A Hybrid Intelligent Autonomous Model Developed Using Multi-Agent Systems

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***Abstract*—Complex problem solving and decision making requires integrating two or more intelligent techniques as no algorithm or technique are sufficient to completely solve a problem. The systems developed by integrating different hard computing and soft computing techniques to solve problem are called Hybrid Systems. This paper presents the design, development and implementation of a hybrid intelligent autonomous model. The model is developed in phases, which comprises of different individual agents. This model will be used to analyse workstress related data in real time.**

***Index Terms*—agent, multi-agent, artificial intelligence, hybrid system, neural networks**

I. Introduction

Real world problems are complex and to solve these real world problems more than one technique are applied at times. The techniques referred to as intelligent techniques can be from traditional hard computing or soft computing. This paper gives an overview of the hybrid model that has been developed by combining different intelligent techniques from an agents perspective, the agents are the building block were each intelligent technique is a module in the form of agent. Agents and multi-agents are being used in diverse domain. An agent according to Wooldridge and Jennings is a software or hardware entity that autonomously reacts to changes in the environment through the use of sensors and actuators [1]. Multi-agent system consists of more than one interacting agent. The model is being tested using workstress related data and via the e-portal StressCafé. The StressCafé [2] is an interactive website that is the single point of contact for measuring work stress, generating feedback, sharing information, and bench-marking psychosocial hazards in the Australian workplace [2]. Work related stress affects people from all professions and is a growing concern in Australia and overseas, as it is reported as a common cause of occupational illness. Work stress can be prevented across and within different organisation, if identified and assessed in timely fashion. Workplace stress has been defined as a pattern of emotional, cognitive, behavioral and psychological reactions to adverse and noxious aspects of the work content, the organisation and the work environment. Stress is also defined as an adverse reaction people experience, as a result of pressure at work from job demand, harassment and injustice in the work environment [3]. Thus this model can be used to assess psychological risk by individual user or users from different organisation, allowing any user to take an online work-related stress survey and receive feedback on their stress levels benchmarked nationally. In section II literature review followed by design of the hybrid model in section III, then development of the model in section IV. Implementation and testing in section V and finally conclusion and future works are presented in section VI.

II. Literature Review

Hybrid intelligent systems are computational system that integrates different computational technique; which can then be used to support problem solving and decision making [4]. As different intelligent technique have their advantages and disadvantages, cannot be universally applied to solve any problem, hence integrating the individual intelligent technique and modeling as hybrid system, the limitations of each individual technique is minimized. These systems have multiple parts which interact with each other to solve problem, thus modeling hybrid intelligent system using Muti-agent system (MAS) is suitable. There are three types of hybrid system: 1) Sequential hybrid system, 2) Auxiliary hybrid system and embedded hybrid system. In Sequential hybrid system, the intelligent component are arranged sequentially, as the output from one component is fed as an input to the other component, auxiliary hybrid system on the other hand allows one component to call other component as subroutine or manipulate information accordingly, Embedded hybrid system allow the individual component to be fused in such a way that it seems that one cannot perform without the other component [4], [5], [6], [7], [8]. Agents are computer system that is equipped with capabilities to act autonomously i.e. deciding for themselves what needs to be done to satisfy their design objective and to interact with other agents by cooperating, coordinating and negotiating day to day activities [9]. A multi-agent system may be regarded as a group of ideal, rational, real-time agents interacting with one another to achieve their desired goal [7], [8]. With this concept in mind the hybrid intelligent agent model has been designed, developed and implemented. In next section a detailed design of the hybrid model using multi-agent systems is presented.

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III. Design of the Hybrid Model

Hybrid system are developed by combining two or more intelligent techniques, each of these techniques has particular strength and weaknesses. When these techniques are integrated to solve a problem, each others strength and weaknesses are neutralized to a certain extent, giving a better solution. To develop the hybrid model as shown in "Fig. 1" a multi-agent based approach is considered.

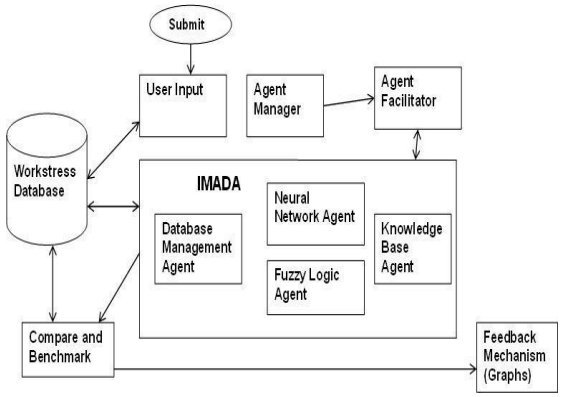

Figure 1. Multi-agent based hybrid model [5]

The Hybrid model consists of:

- Workstress Databases
- Agent Manager
- Agent Facilitator
- IMADA
- Feedback Mechanism

The Workstress database will contain, survey questionnaire, the user survey data, the data for benchmarking. The agent manager and agent facilitator manages the different agent by message passing. The feedback in real time is generated and presented to the user via the feedback mechanism [10].

The intelligent multi-agent decision analyzer (IMADA) is the main backbone for the model. Within IMADA the different intelligent technique are constructed as individual agents and then integrated to perform as a whole system. The individual agents are equipped with capabilities required to function independently, but communicates with the other agents to accomplish the common goal. IMADA comprises of four individual autonomous agents which can function independently, and also interact with the other agent to accomplice their desired goal. The different agents are:

- Database Management Agent,
- Neural Network Agent,
- Knowledge Base Agent,
- Fuzzy Logic Agent.

The next section presents stages of the model development from the design phase.

IV. Development of the Model

The model consists of four agents, these agents are constructed as individual modules equipped to function independently, but interact with other agents to accomplish common goal. Brief descriptions of each agent are given below:

A. Database Management Agent

The database management agent manages the databases. The user database stores information from the survey undertaken by user of the system. The national benchmark database stores data that are collected by conducting survey. The intelligent multi-agent based analyzer, analyses and benchmarks the data. As the data increase in volume, at some point in time based on a threshold value, the data from the user table needs to be uploaded to the national benchmark table after pre-processing the data. This becomes tedious if it has to be pre-processed and appended manually as data increases exponentially. Especially when the interval is unknown, this may also compromise efficiency and effectiveness [11].

B. Neural Network Agent

The neural network agent is a neural network that uses the backpropagation algorithm that is being programmed using the programming language Java, as that suits our requirement. Neural networks were developed with a view of creating machine that can function as to how the human brain works; the machines are built from components that behave like biological neurons. Neural network are pattern classifiers, which takes in an input pattern and produces an output which is correct for that particular class. The network has the ability to learn and generalise [12], [13], [14].

A backpropogation network consists of:

- an input layer
- one intermediate hidden layer at least
- an output layer

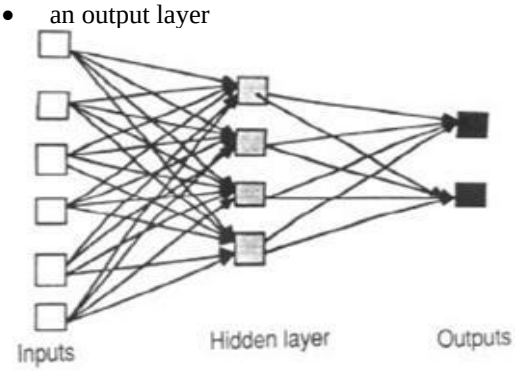

Figure 2. Multilayered perceptron (10)

The unit or nodes of the network is connected to the hidden layer and then connected to the output layer. When an input pattern is presented to the network it is propagated forward to the output units through the hidden layer with weights adjusted along with an activation function. The pattern presented at the output layer is compared with correct output pattern, if there is an error signal then the error signal for each targeted output is propagated backwards via adjusting weights, and is continued until the networks learns to classify correctly [12], [13], [15].

The feed forward network can be represented as:

$$y = F(x) \quad (1)$$

where, x= (x_1, x_2, ……,x_N) and y = (y_1, y_2,……y_M). For a network with N input nodes, H hidden nodes and M output nodes, the value y_k are given by:

$$y_k = g(\sum_{j=1}^{h} w_{jk}^{o} h_j), k = 1 \ldots M \quad (2)$$

Here, w_{jk}^{o} is the output weight from the hidden node j to the output node k, and g is a transfer function. Let E be the total error, for the network and T the expected output and O the actual output, and then the error function is computed using formula 3:

$$E = \sum_{k=1}^{K} E_k = \sum_{k=1}^{K} \left(\frac{1}{2} \sum_{i=1}^{N_i} [T_i(k) - O_i^L]^2 \right) \quad (3)$$

The sigmoid transfer function is:

$$y = \frac{1}{1+e^{-x}} \quad (4)$$

C. Knowledge Base Agent

The Knowledge base consists of facts and rules about the subject at hand, presently it contains knowledge from psychology, mostly relating to the workstress survey questionnaire terminology. Domain knowledge along with rules from psychology and artificial intelligence are being added to the knowledge base.

D. Fuzzy Logic Agent

The fuzzy logic agent maps the numeric output from the neural network to linguistic variable. A fuzzy set A is defined by a set or ordered pairs, a binary relation, where, $\mu_A(x)$ is a function called membership function; $\mu_A(x)$ specifies the grade or degree to which any element x in A belongs to the fuzzy set A.

$$A = \{(x_1 \mu_A(x)) \mid x \in A, \mu_A \in [0,1]\} \quad (5)$$

each element x in A is a real number $\mu_A(x)$ in the interval [0, 1] which is assigned to x. Larger values of $\mu_A(x)$ indicate higher degrees of membership [16], [17], [18].

V. Implementation of the Model

The different intelligent technique are individually programmed and then integrated and implemented. The model is implemented and tested online as well as offline using the e-portal StressCafe. The StressCafe is an e-portal that hosts on-line surveys and provides e-feedback to aid the translation of research into policy and practice, also it is intended that the website will provide e-therapy and e-counseling along with the nationally significant workplace surveys. This is a one stop web-shop which can be accessed by industry, individuals, government bodies, communities to collect, compare and share information in relation to work related psychological risk [5],[10], [11], [19].

Within the StressCafé using the Australian workplace barometer tool (AWB) online the hybrid intelligent model is implemented and tested using data collected via survey from six states and territories within Australia.

The data collection commenced in the year 2009, completing four waves of collection in the year 2011. The present study uses data that has been collected from four Australian States New South Wales (NSW), Western Australia (WA), South Australia (SA) and Tasmania (TAS). Data was also collected from two Australian Territories Australian Capital Territory (ACT) and Northern Territory (NT) [20].

A. Case study with special emphasis on Depression

The collected data was preprocessed and stored by the database agents as these data were collected from various states and territories across Australia; they will be used to benchmark individual user score nationally. The Benchmarking database is also being updated with user data based on a threshold value which was 50 in this case. As user takes the online survey, their data is preprocessed and analysed by the neural network agent. As mentioned in section 3 a backpropogation neural network is used.

The neural network takes five parameter input: {*Industry, User Mean, Total Mean, Mean+2SD, Mean-1SD*} which are chosen as the user level of work stress will be benchmarked based on the industry they work. The user mean for a particular section of the questionnaire (*depression in this case*) is calculated. The Total mean is the mean calculated for the same section of the questionnaire data collected nationally. The standard deviation (SD) for the user mean for depression is calculated [11].

The network consists of:

Inputs: {5}

Desired Output: 1 {O} (the output from the network), one output

Weight = *W*, the weights are assigned randomly.

Learning rate = η

Hidden neuron = 6

Hidden layer = 1

The sigmoid transfer function used is as given in "(4)," which is considered as it is the best optimizer for this case.

The output from the neural network as can be seen from Table I is in a numeric form or crisp form, which is processed by Fuzzy logic agent. The fuzzy logic agent trans forms the crisp values into grades of membership for linguistic terms, very high, high, medium, low, very low of fuzzy sets as shown in Table II. The fuzzy output is stored and presented to the uses via the feedback mechanism.

Table I shows the input and desired output from the neural network.

TABLE I. Input and Desired Output From the Neural Network

INPUT					OUTPUT
Q8B	Mean Total	Mean+2SD	Mean-1SD	Depression per user	Output
4	2.7368	9.6134	-0.7014	13.6060	5
10	3.8433	11.8533	-0.1616	4	4
13	3.6797	11.1412	-0.0509	6	5
10	3.8433	11.8533	-0.1616	1	2

TABLE II. RESULT FROM THE NEURAL NETWORK

INPUT			OUTPUT		
Q8B	Mean Total	Depression per user	Target Output	Network Output	Fuzzy Output
4	2.7368	13.6060	5	4.4505	High
10	3.8433	4	4	3.9685	High
13	3.6797	6	5	4.3401	High
10	3.8433	1	2	2.2602	Low

The model provides feedback as shown in "Fig 2" to participants who complete a work-based psychosocial risk assessment survey by comparing individual results to AWB benchmark scores in the form of graph and table. The user can also retrieve information regarding there psychological risk or terminologies from the knowledge base clicking on the links provided.

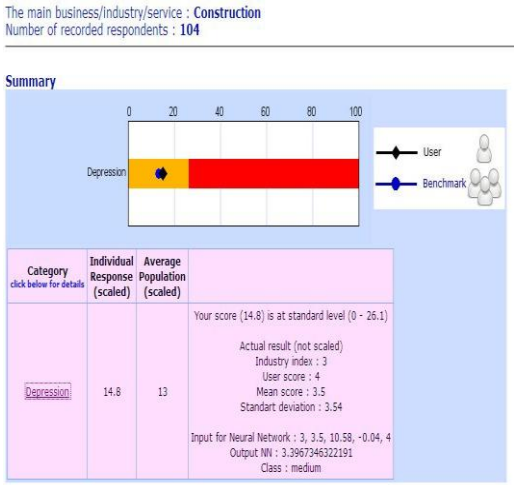

Figure 3. Benchmarked user feedback summary via the stresscafe.

From the Summary shown in "Fig. 3." the bar graph represents the user score in black where as the grey score represents nationally benchmarked data on a 0-100 scale for Depression. The summary also gives the users response alongside the average population response (Benchmarked Data) that this particular user is at a standard level.

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