Comparative performance Analysis of the Machine Intelligent Quotient (MIQ) and Human – Machine Cooperative Systems

Rapelang R. Marumo

Department of Mechanical Engineering

University of Botswana

Gaborone, Botswana.

marumorr@mopipi.ub.bw

Abstract - *This paper presents results of investigation into the development of a measurement of the machine intelligent quotient (MIQ) criterion. This scheme has been devised as an alternative to the traditional human to human natural way of conducting a survey type search. Information in control engineering education awareness results (data) is stored in the computer for ease of retrieval as and when necessary. A plethora of existing intelligence-based modelling and control strategies biased towards cybernetic techniques such as forecasting, prediction and training have been utilised for the purposes of identification, modelling, simulation, analysing and evaluation. A comparison of traditional search approaches and the new improved cybernetic search technique has shown that the improved technique has yielded better results. The cybernetic balance search method can be automated. Past and current data can be retrieved and future trend of data be predicted at the touch of a button, and the results have shown that, when optimally formulated, performance of the cybernetic system can be enhanced, either by explicit optimisation methods or extensive computation. This research will help researchers to asses intelligent machines that are designed to perform human-like qualities with a high degree of autonomy.*

Keywords: Cybernetic systems, human computer integrating, intelligent systems, machine intelligent quotient (MIQ), control engineering education.

1 Introduction

Complex systems, in particular information flow such as (command, control, communication computer intelligence, surveillance and reconnaissance) systems exhibit an increasing dependence on the nature and flow of information in the system. For this reason it is both the flow exchange of information in the system and the emergent information properties of the system, which are central to the definition, design and analysis of such systems. At the same token, while the operational concept of information is well defined, it is at the system and the technical levels where information is comparatively poorly understood and inadequately modelled. Not until the exchange of information between system elements, or subsystems, can be defined, in terms of broader information properties such as quality and definition will the means exist to control system behaviour in this respect. Further evidence of requirements for a broader model of information flow exists in the cybernetic information flow domain. In this paper, some of the general concepts of information and quality, are raised. The nature of information in cybernetic survey systems is discussed. The paper describes model information and its potential for application to the flow and exchange of cybernetic information. The model which is described uses qualitative approach to information. This approach seeks to understand and qualify the nature and meaning of information in a system. The advantage of applying a qualitative model of information to the definition, design and analysis of cybernetic information flow systems may include optimisation of information exchange for non-quantitative factors, prioritisation of information flow and deeper understanding of emergent properties of the system with respect to information in the system [1]. The semiotic model may be summarised as follows:

- Information arises in systems. This information has two related aspects.

- Symbolic meaning that establishes the quantitative aspects of information. This is governed by information theory. The qualitative aspects of information are governed by three successive semiotic levels that cater for relationship between symbols, the relation of symbol to object and the relation of symbols to values or goals. Main concepts emanating from the findings are:

- Cybernetic models can mimic information systems very well.

- There is need for a qualitative model of information that may be applied to the definition, design and analysis of cybernetic information systems.

1.1 Related work

To put this research work into perspective, the existing information retrieval methods are discussed for critical review and comparison purposes. The reviewed approaches to which the proposed cybernetic balance search (CBS) technique conforms to the human affect recognition, textual affect modelling and online virtual training environment (VTE). Artificial intelligence (AI) is the research area for implementing intelligence in machine which is one of the human characteristics based on computer science, biology, ecology, philosophy, mathematics engineering and so on. AI has begun to substitute human knowledge/ intelligence as well as physical labour. After Simon et al. first introduced AI in 1956, various definitions of machine intelligence has been published [2-6]. In this research work, the term intelligent control means some form of control using neural networks, fuzzy logic control and evolutionary techniques [7-8]. Chalfant proposed a measure of system intelligence that can be modelled by the robot description language (RDL) [9]. However, it may be difficult and unrealistic for engineers to code machine behaviour with the hypothetical language RDL. Bien [10-11] introduced the machine intelligent quotient (MIQ) as a new index to represent machine intelligence for the first time. Bien defined the MIQ and proposed two measurements methods, the ontological and the phenomenon logical method. However, these methods are too general and real world control systems cannot be modelled. The main limitations of using these methods are the following:

- It is difficult to select weighting factors that properly represent the measurement purpose and guarantee the independency among factors
- Determining weights has the possibility of controversy depending on viewpoints
- The relation between the index and its factors is actually nonlinear

1.2 Human affect recognition

In order for an adaptive information retrieval system to respond to human affect, the system must first be able to sense and recognise users' affective state [12]. The sensing medium can be broken into three categories of textual, audio, visual and physiological. In [13], it has been demonstrated that affect signals maybe derived in many ways.

1.3 Textual affect modeling

This modeling approach analyses text to estimate the effective state of the user. The model approach ranges from the simple keyword spotting to more sophisticated techniques such as assigning probabilistic affinity of these key words and statistical natural language processing approaches [14].

1.4 Online virtual training environment

The potential of VTE technology for supporting education is widely recognized [15-17]. This used centered education delivery approach has been implemented in [18] for the aid of people with disabilities. The approach demonstrated superior benefits compared with the two mentioned approaches because it:

- Limits the cost constraints in 'learn-by-doing' institutions
- Provides a unique vantage point for learning by placing the user in a simulated world
- Provides different framework to scaffold education

- Provides quantitative and qualitative information from which to distil the tutorial strategies necessary for developing intelligent agents (IAs).

As a baseline, the improved (MIQ) herein presented has been modelled to mimic the VTEs. Normally, computer controllers cannot complete overall control jobs without human supervisors. The entire control system is made up of human supervisors and machines. Considering this realistic control environment. The human-machine cooperation model and the intelligence cybernetic balance model a re proposed as a modelling and analysing tools for measuring real machine intelligence. This paper is organised as follows Section 2 describes the application of cybernetic networks and their role in control engineering education. Section 3 discusses the application of adaptive cybernetic information retrieval methods. A summary of overall discussion and future work are presented in Section 4. The paper is concluded in Section 5.

2 Cybernetic networks and their role in control engineering education

A cybernetic system is a distributed system where there is no centralised control. The system is behaviour emergent being a result of interactions and feedbacks among the actors, participants or agents in the network. As explained in [19], the typical property in cybernetic system is it's striving towards balance. That is, all organisms reflect some balance and actions reflect strive towards better balance. Cybernetic system information can be defined from an operational perspective in terms of task, activities, operational elements and information flow that is required to be accomplished by a command style communication e.g military operation. In this domain, information of the refinement of data through known convention and context for purposes of imparting knowledge. Associated definitions of information in cybernetic systems and MIQ are dealt with comprehensively in [20]. Similar to the intelligence quotient (IQ) used for human intelligence; the MIQ is an index used to asses the intelligence of a control system. Therefore, the MIQ differs significantly from other well-known indices such as control performance, reliability, fault diagnosis capability and others.

2.1 Cybernetic system identification and modelling

In cybernetic modelling, the identification method used is very important. Identification for semiotic modelling has two aspects: structure identification and parameter identification. In general, structure identification is a difficult and extremely ill defined process and not readily amenable to automated techniques. The problem of parameter identification is closely related to the estimation of the membership functions of the fuzzy sets or alternatively, the fuzzy relation associated with the fuzzy model.

2.2 Structure identification

Generally structure identification constitutes two problems. Firstly, to find input variables from a number of input candidates by a heuristic method based on experience and/or common sense knowledge. Table 1 shows part of the survey results, being five questions and their respective answers as obtained from some five of the surveyed companies in Botswana. Existing complex systems like control engineering survey result shown in Table 1, have not knowingly been designed to be cybernetic, but because of the inevitable compromises, interactive feedback structures been anyway have integrated there. It is therefore not a once for-all design, but one typically that has to be reconstructed and fixed and continually tuned as semiotic systems dynamic change.

2.3 Defining an index: MIQ

Before developing the intelligence measure, it is important to review some well-known definitions of machine intelligence. The following statements show the attributes intelligent machines should have:

- Machine intelligence is the process of analysing, organising and converting data into knowledge, where machine knowledge is defined as the structured information acquired and applied to remove ignorance and uncertainty about a specific task pertaining to the intelligence of machine.

- In order for a man-made intelligent system to act appropriately, it may emulate functions of living creatures and ultimately human mental faculties.
- Intelligent control is the discipline in which control algorithms are developed by emulating certain characteristics of intelligent biological systems.
- An intelligent control system is a control system with the ultimate degree of autonomy in terms of self-learning, sefl-reconfigurability, reasoning, planning and decision making
- Intelligent machine are machines that are designed to perform anthropomorphic tasks with minimum iteration with a human operator.

Table 1: Sample questionnaire

QUESTIONS	COMPANIES				
	A	B	C	D	E
1.Does your company automate any of its processes?	Y	Y	Y	Y	Y
2. If you have automated plant, what kind of controllers do you use (PLs, PIDs)?	B	Ns	Ns	B	B
3. Do you have a dedicted control / instrumentation team?	Y	N	N	Y	Y
4. Are your controllers ? analogue or digital	D	Ns	B	B	D
5. Do you know if any of your control plants are based on modern control techniques?	Y	N	N	Y	Y

KEY: A, B, D, N, Ns and Y denote Analogue, Both, Digital, No, Not sure and Yes respectively

Learned and learning systems are human beings and react to their internal and external environments [21]. A collection of data shown in Table 1 is interface between the machine a human supervisor by means of computer software. This is referred to as machine-human computer interface control (MHCIC). A schematic of the MHCIC technique is shown in Fig. 1.

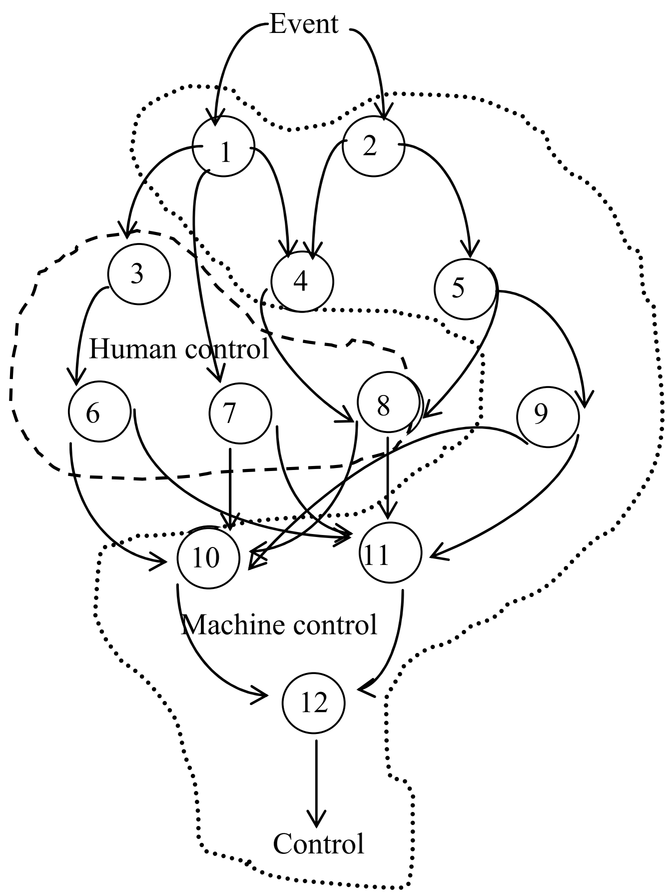

Figure 1Human-machine control architecture

Interfacing complexity means the transferring of one unit of data between the human and machine through display devices, keyboards, control switches, mouse and so on. C_{hm} is the interface complexity for transferring data from human to the machine and C_{mh} from the machine to human. Interface intelligence cost functions are denoted by $f_{ij} . c_{mh}$ and $f_{ij} . c_{hm}$. The human must understand the displayed plant data and give the machine control commands to exchange information with the machine. The human intelligence amount required to communicate data with the machine is the intelligence cost function which is proportional to both data quantity and interface complexity. In task allocation matrix A, the elements of matrix A can be only be binary values: 0 or 1. $a_{i1} = 1$ if the machine performs T_i and $a_{i2} = 1$ if the human performs T_i. If T_i can be assigned to neither the machine nor the human, $a_{i3=1}$. Hence, $a_{i1}+a_{i2}+a_{i3}=1$ for $\forall i, 1 \le i \le n$. The n by 3 matrix A can be defined as:

$$A=\begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \\ \vdots & \vdots & \vdots \\ a_{n1} & a_{n2} & a_{n3} \end{bmatrix} \tag{1}$$

If the control intelligent quotient (CIQ) is the apparent intelligence of the overall control system containing the human and the machine, therefore the CIQC is the sum of all task intelligence const functions and

$$C=\sum_{i=1}^{n} a_{i1} \bullet \tau_i + \sum_{i=1}^{n} a_{i2} \bullet \tau_i \tag{2}$$

If the human intelligence quotient (HIQ)H be the intelligence quantity required from the human for controlling plants, then

$$\begin{aligned} H=&\sum_{i=1}^{n} a_{i2} \bullet \tau_i + c_{mh} \sum_{i=1}^{n}\sum_{j=1}^{n} a_{i1} a_{j2} f_{ij} \\ &+c_{hm} \sum_{i=1}^{n}\sum_{j=1}^{n} a_{i1} a_{j1} f_{ij} \end{aligned} \tag{3}$$

Since H the sum of the task intelligence cost functions allocated to the human and interface intelligence cost functions. By subtracting H from C, the following can be obtained:

$$M = C - H \tag{4}$$

MIQ can be divided into two portions: the machine control intelligence M_C and the machine interface intelligence M_F. With simple manipulation, the following can be obtained:

$$M = M_C + M_F \tag{5}$$

where $M_C = \sum_{i=1}^{n} a_{i1} \bullet \tau_i$ (6)

$$M_F = -\left(c_{mh} \sum_{i=1}^{n} \sum_{j=1}^{n} a_{i1} a_{j2} f_{ij} + c_{hm} \sum_{i=1}^{n} \sum_{j=1}^{n} a_{i1} a_{j1} f_{ij} \right) \quad (7)$$

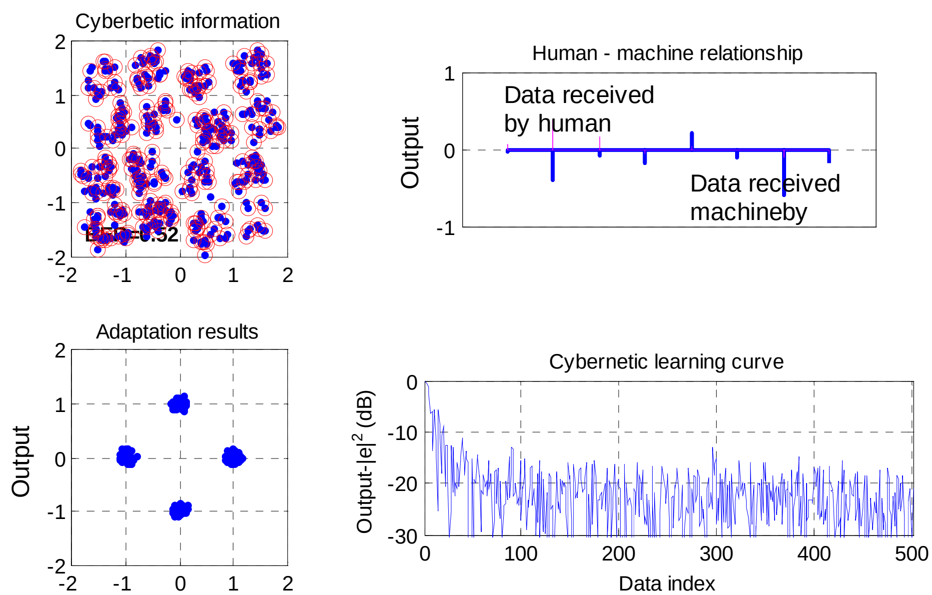

Figure 2 Decision feedback adaptation

A two part MATLAB source code script simulates a communication link with human-machine modulation scheme, raised-cosine pulse shaping, multipath fading and adaptation algorithm. The first path sets simulation parameters and creates channel and adaptation objects. Part two performs a link simulation based on these settings, which are stored in the MATLAB workspace. Part one also sets up three adaptation scenarios and calls part two multiple times for each of theses. Each call corresponds to a transmission block. The pulse and multipath fading channel retain state information from one block to the next. For visualising the impact of channel fading on adaptive equaliser convergence, updates parameters and the simulation resets the adaptation process every block. Set parameters related to human machine modulation and the transmission block. The block comprises the contiguous part: training sequences, load categorisation and learning sequence. The training and learning sequences are used for adaptation. A structure is created, containing cybernetic information about the transit and receive filters of the cybernetic balance engine. Each filter has a square root raised cosine frequency response, implemented with an FIR structure. The transit and receive filters incorporate unsampling and downsampling, respectively and both us an efficient polyphase scheme. These multirate filters retain state from one transmission block to the next, like channel objects. The peak value of the impulse of the filter cascade is 1. The transmit filter uses a scale factor to ensure unit transmitted power. As indicated in Fig. 2, the receiver used decision feedback adaptation (DFA) with a six-tap fractionally spaced forward filter and feedback weights. The DFA uses the recursive least square algorithm (RLS). The receive filter structure is reconstructed every sample to account for the increased number of sample per symbol.

As a follow on of results in Table 1, a cybernetic balanced high-order model can be deduced as depicted in Fig. 3.

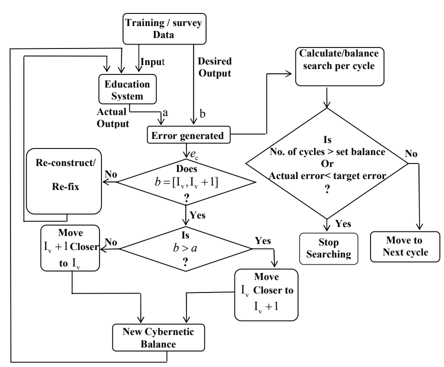

Figure 3 Cybernetic balance search system

Key: e_c, Δe, I_v, I_{v+1}, a, b represent control error, change in error, input variable, past input variable, actual output and desired output respectively. The actual output signal, is generated by the controller and the control signal error, is generated as the difference between the desired output, b and a . In total, 75 data points comprising input / output results from 5 surveyed companies in Botswana, were stored in a data file and supplied to the MATLAB environment as script m-file for qualitative / quantitative analysis and training/ simulation purposes. In this system, the variables are based on probabilities or relevance. No linear assumptions can be made. Probabilities of independent variables typically have to be multiplied to achieve meaningful results. For example, the overall risk of candidates to miss out from control education outreach is proportional to a product of two factors: namely, the overall deficiency in education outreach and the probability that the deficiency in outreach affects specific areas (i.e. small villages and so called remote dweller's settlements). To continue with the cybernetic considerations, an assumption is made that: in the cybernetic system, the relevancies are in static balance and a set of equations holds:

$$\begin{cases} \left(\dfrac{z_1}{z_1}\right)^{a_{11}} \cdots \left(\dfrac{z_n}{z_n}\right)^{a_{1n}} = \alpha \left(\dfrac{\mu_1}{\mu_1}\right)^{b_{11}} \cdots \left(\dfrac{\mu_m}{\mu_m}\right)^{b_{1m}} \\ \vdots \\ \left(\dfrac{z_1}{z_1}\right)^{a_{n1}} \cdots \left(\dfrac{z_n}{z_n}\right)^{a_{nn}} = \alpha n \left(\dfrac{\mu_1}{\mu_1}\right)^{b_{n1}} \cdots \left(\dfrac{\mu_m}{\mu_m}\right)^{b_{nm}} \end{cases} \tag{8}$$

Where: z_i represents positive system variables and μ_i represents external inputs. Logarithmic representation of equation (8) yields:

$$\begin{cases} a_{11} \log z_1 + \cdots + a_{1n} \log z_n = c_1 + b_{11} \log \mu_1 + \cdots + b_{1m} \log u_m \\ \cdots \\ a_{n1} \log z_1 + \cdots + a_{nn} \log z_n = c_n + b_{n1} \log \mu_1 + \cdots + b_{nm} \log u_m \end{cases} \tag{9}$$

Where: the constraints c_i contain the contributions of the operating values $\log \bar{z}_i$, $\log \bar{\mu}_i$ and other constants as collected together. $\bar{z}$ and $\bar{\mu}$ represents normal values of z and μ respectively. In this respect, linear representation of a cybernetic system can be recovered, such that when written in a matrix form, static cybernetic model can be represented as:

$$Ax = Bu \tag{10}$$

A can be interpreted as a stable system matrix and the original framework can be changed into a dynamic equilibrium process striving towards a cybernetic balance i.e.

$$\frac{dx}{dt}(t) = -\mathrm{A}x(t) + Bu \tag{11}$$

This approach shows that, the model structure remains intact, no matter whether variables are linear or nonlinear (logarithmic) and these two models can be constructed in the same way. However, cybernetic subsystems with different types of variables are mutually incompatible and thus, cannot be directly connected without variable transformation.

2.4 Cost function and cybernetic balance search criteria

The method by which potential solutions are assessed is a critical component for a cybernetic balance search to be reached. Typically, technical tasks can be formulated as optimisation problem. When optimality is formulated, the system performance can be enhanced, either by explicit optimisation methods or by extensive computation. If the cost function is inappropriate then the cybernetic balance search is unlikely to progress in an acceptable direction. Initially the raw performance measures (objectives) must be defined. This is very much an application dependent process. The next consideration is the means by which the performance data will be obtained, this is often model based. The raw performance data must then be translated into a non-negative scalar or fitness value. Many engineering problems consist of multiple objectives leading to associated multiplicative systems and for the purpose of an equilibrium cybernetic balance search, these must be combined to form a single value. The simple routine adopted is based on De Jong's first test function. The objective function is defined as described by equation (12).

$$\mathrm{J} = \max \sum_{\mathrm{k}=0}^{\mathrm{N-1}} \sqrt{\mathrm{uk}}, \quad [-0.4 \le \mathrm{u} \le 0.4] \tag{12}$$

Where: N represents the number of control steps over which the problem is to be solved, and u is the control input. Note that this is a maximisation problem and the cybernetic balance search routines are implemented to minimise this objective function, i.e. J is multiplied by -1 to produce a minimisation problem.

OR

$$f_1(x)=\sum_{i=1}^{N} x_i^2, \quad [-30 \le x_i \le 30] \tag{13}$$

This optimisation technique can be used as minimisation problem or maximisation problem as in equation (13). The mechanism depends on the user. In this study, the approach used was to maximise the function:

$$z = f(x,y) \tag{14}$$

Where: z represents the parameter to be maximised, x and y are the considered ranges. f represents the fitness function and must always be positive. Cybernetic optimisation criteria are mutually inconsistent and the key issue is how to formulate the optimality criteria appropriately.

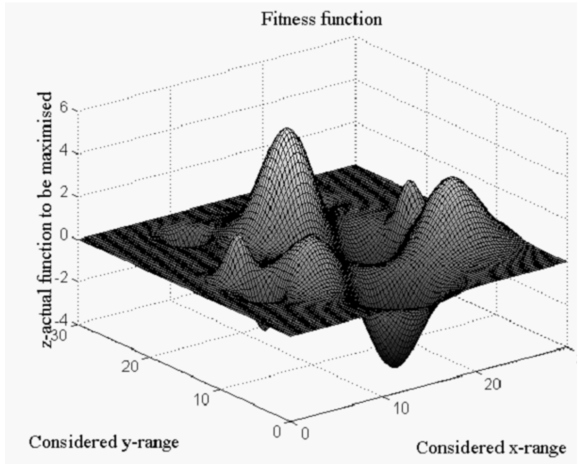

Figure 2: Optimisation function

To achieve a well-defined optimisation solution, the different criteria have to be combined, for example, by appropriate weighting, so that the final cost criterion becomes:

$$
\begin{aligned}
\mathrm{J}(x,\lambda) &= C_o(x) && \text{Production cost} \\
&+\rho(\mu\text{-}\varphi x)^{\mathrm{T}}(\mu-\varphi x) && \text{Predetermned profiles} \\
&+\sigma(\mu\text{-}\phi x)^{\mathrm{T}} W(\mu-\phi x) && \text{Cybernetic cost}
\end{aligned}
\tag{15}
$$

Where: ρ and σ represent weighting factors for emphasising different criteria. x and μ indicate that there are constraints so, $\sum_i \bar{x}_i = \sum_j \bar{u}_j$ assumption must hold.

3 Adaptive cybernetic information retrieval model

The aim of the adaptive information retrieval model is to provide content in such a way that the user is brought closer to some predefined affects state. The program evaluation and feedback from the representative users provides valuable qualitative and quantitative data for future analysis. Refinement of the program needs to follow the knowledge from analysis of results [22]. The design cycle is based on the usual principle of design i.e., implementation, evaluation, analysis and modification of the process to fulfill the requirement of the user and design team. The adopted design cycle is shown in Fig. 2.

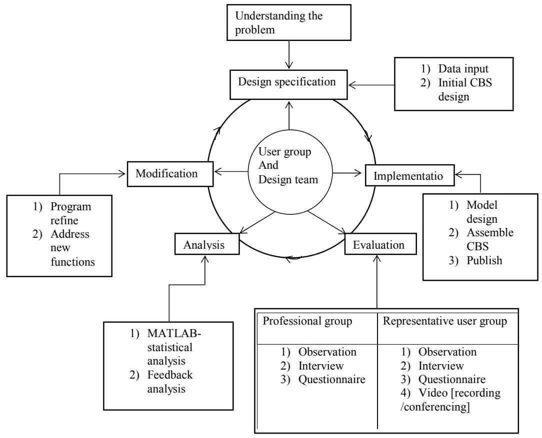

Figure 3: CBS -user-centred design methodology

This model is defined by the following parameters:

- A set of affect states, analogous to the hidden layers in the neuro-fuzzy network
- A user specific goal state analogous to the error goal parameter in the neural network system
- A set of content categories, representing the input/output mapping of data set
- Content influence matrix, $C = \left(c_{ij}\right)$, analogous to [R S] matrix indicating the size of the input and output layers respectively.

The content categories represent group of information that should be provided given the current affect state i and the user goal affect state j . For a start, the content influence matrix is initiated manually with a view to automate it in future. A typical CBS content update algorithm is given as follows:

Let
T: represents number of collected samples
since last innovation
φ: represents minimum sample size
For each sample, the following tuple is stored
ρ: previous affect state
σ: goal affect state
c: chosen category

Compute the number of occurances for all pairs $\{\rho\text{=i}, \sigma\text{=j}\}$
Where 1 $\leq i, j \leq n$

For all occurances of $\{\rho_{\text{i}}, \sigma_j\} \geq \varphi$,
Compute the highest occurance c
Update $\text{c}_{\text{ij}} = c$

4 Discussion and future work

Future work aims to investigate the implementation of IAs in CBS prototypes for the target education framework and to evaluate its usability by comparing its performance accuracy with and without agents. The learning scheme will basically involve the selection of better N-tuples in an iterative manner, which is one of the oldest pattern recognition methods that have been successfully used in many applications. When the particle swarm is applied on the Ntuple, the tuples of the N-tuple can be termed particles. Thus each particle corresponds to an input connection map of the N-tuple network [23]. The particle swarm technique makes use of a population of particles or input-maps (for N-tuples), where each particle has a position, a velocity and the rate at which it can travel (acceleration).

5 Conclusion

The study reported herein, was an inquiry into the modelling of the information flow in order to formulate a control education referendum using cybernetic balance search techniques. Initial findings in this research are promising and thus suggest that the developed model can form the basis of a network with rich knowledge based- data that can be used for cybernetic education referendum framework. The MIQ has been defines as the measure of machine intelligence and presented using systematic assessment methodology, which extracts machine intelligence from a human-machine cooperative system. An optimisation process based on cybernetic information search balance has been implemented in typical control education awareness results characterising a cybernetic system. Practical constraints influenced the way in which the search criterion was implemented. The derived model can be a good tool in the implementation of control engineering strategies in industry and for planning at institutions that teach control engineering and related subjects. The proposed measuring procedure has been verified from the examples of supervisory control of power plant.

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