یازدهمین کنگره ملی سراسری
فناوریهای نوین در حوزه توسعه پایدار ایران
11th National Congress of
the New Technologies in Sustainable Development of Iran
senaconf.ir

An Analytically Algorithm for Tuning of BELBIC Controller

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Abstract— **In this paper an analytically approach is investigated for tuning of BELBIC controller. BELBIC is an intelligent controller based on the model of the emotional part of brain. It has concluded that changeable parameters in BELBIC provide better performance in different conditions of a particular control trend. Some approaches have introduced to discuss system stability.**

Keywords-component; formatting; BELBIC, Stability Analysis, Performance Analysis

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1. INTRODUCTION

At the different efforts witch were done in 80^{th} decades, for cognition of emotional deciding process, the emotional system was introduced as an expert system [1], [2]. In newer approach, proposing the computational model from the parts of brain that are responsible for emotional processing is considered. In the methods based on computational models, the emotions are such an external environment representation signals. In psychological researches, the emotions are evaluated as a canonical of feeling determination [3].

Scientist believe that in order to Morer Theory, the system of Amygdala-orbitofrontal performs the learning in two steps. At first the input stimulating signals are evaluated and then this evaluation is used as an amplifier and the factor of response due to stimulation. The advantage of this method is the response and the stimulation are completely distinguished. the computational model of Amygdala-orbitofrontal which is taken from Moren and Balkenius, [4], [5], [6], is proposed and this computational model is used as controller was named as BELBIC.

BELBIC has turned to be a popular method in multi objective problems, especially those with several goals in contrast [7-10]. Since it has inferred from brain activity model of mammalians [11], the mathematical formulations is simple and easy to understand. Besides, not much computational operation is necessary. This controller is known to be a robust one with satisfactory but not optimum response [6, 7]. In a formal definition, BELBIC is said to be an action generator based on two emotional inputs: Sensory Input (SI) and Emotional Cue or Reward Signal (Rew) [12] and the most interesting concept of BELBIC is flexibility in definition of SI and Rew formulation depending on control problem [6].

Sensory Input is determined according to plant significant properties such as error and indicates the cognitive understanding of plant situation for control system. Frankly speaking, it contains the cognitive meaning of technical observations. On the other hand, Rew is an internal reinforcement signal which navigates BELBIC during operation. Emotional inputs may appear in generally different formulations [1, 4] which directly affect the performance of controller. Even same formulations have different coefficients which should be set accurately since bad setting might cause low robustness or system instability. There have been rare efforts to find a way to determine the structure of BELBIC and its emotional inputs.

Jafarzadeh et. Al [14] has proposed a method to determine the learning rates of Amygdala (which encourages the plant cur- rent state) and Orbitofrontal cortex (which condemns plant current state) for a first order linear system. Milasi et. Al [3] utilized genetic algorithm to assign proper values to learning rates. Rouhani et. Al [1] has assumed Sensory Input as a simple PID and applied well-known methods like Zigler-Nichols to tune the parameters to achieve an initial point for coefficients. This paper first explains the under control model and its properties. Then it introduces an analytically approach is investigated for tuning of BELBIC controller. Stability Analysis is considered By MATLAB/Simulink.

2. IMPLEMENTION OF BELBIC

In this research the computational model of Amygdala-orbitofrontal which is taken from Moren and Balkenius, [11-12], is proposed and this computational model is used as controller. In Brain emotional learning based intelligent controller which is considered in this research, the excitement factor as a negative factor appeared with critic is produced and it will perform the adjustment of controller parameters.

Amygdala is a part of brain which is responsible for emotional processing and it relates to sensory layer of Thalamus and layer of orbitofrontal. In computational model, amygdala and orbitofrontal have reticular structure that in which there is a node for each sensory input. In amygdala, there is also another node for thalamus input that the value of this input is equal to the maximum value of sensory inputs.

The outputs of nodes in amygdala and orbitofrontal layer are calculated in order to (1) and (2) equations respectively [12]:

$$A_i = S_i V_i \qquad (1)$$

$$O_i = S_i W_i \qquad (2)$$

Where A_i and O_i are the node outputs in reticular structure for amygdala and orbitofrontal respectively, W_i and V_i the node weights and S_i's are the sensory inputs. Changes in W_i and V_i in learning process are calculated by using of (9) and (10) equations respectively. By considering of $[x]^+ \equiv \max(o, x)$:

$$\Delta V_i = k_a (S_i [R_w - \Sigma_j A_j]^+) \qquad (3)$$

$$\Delta W_i = k_o (S_i (E' - R_w)) \qquad (4)$$

$E' = \Sigma_i A_i - \Sigma_i O_i$ (without considering thalamus input)

Where K_a and K_0 are learning coefficients that with their adjusting, the time of learning will be adjusted. As it seen the values of A_i can't be decreased; it means that amygdala won't forget the learnt information. In fact forgetting or preventing is the duty of orbitofrontal layer and finally the model output will be obtained from equation (11):

$$E = \Sigma_i A_i - \Sigma_i O_i \qquad (5)$$

Fig.1 shows the brain emotional learning based intelligent controller (BELBIC). The amplified signal R_w of sensory inputs are calculated in order to system output, control signal and their own values with (12) and (13) equations respectively. Their general form is like below:

$$R_w = J(S_v S_2 ...., S_n, E, PO_1, ...PO_m) \qquad (6)$$

$$S_i = f(E, PO_1, ...PO_m) \qquad (7)$$

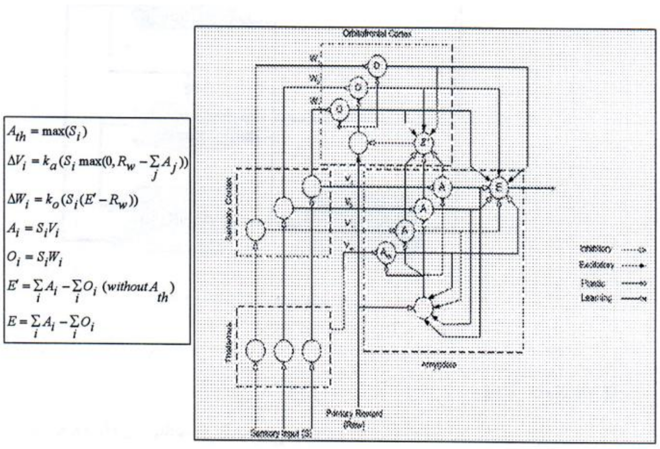

Figure. 1. Computational model of brain emotional learning system [12]

It also must pay attention that k_a and k_b are the primary values of A, A_{th} , O and the function of J, F must be chosen properly which in emotional controller designing part, it will be discussed how they will be chosen.

By ignoring the details, the figurative design of brain emotional learning system is shown in Fig. 2.

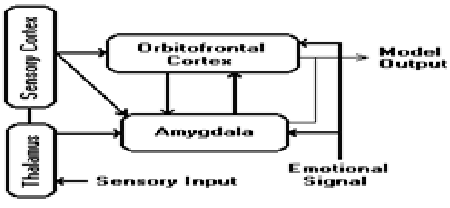

Fig.2. Parochial demonstration of computational model proposed by brain emotional learning mechanism

The output of computational model of MO (response to amygdala-orbitofrontal emotional learning system by input SI stimulating and emotional signal of reward and punishment EC).

$$MO = AO - OCO \qquad (8)$$

Where OA and OCO are the outputs of amygdala and orbitofrontal units respectively and equal to:

$$\begin{aligned} AO &= G_a \cdot SI \\ OCO &= G_{oc} \cdot SI \end{aligned} \qquad (9)$$

G_a and G_{oc} are the equivalent gain of amygdala and orbitofrontal units. The rule of learning in amygdala and orbitofrontal units is as below respectively:

$$\begin{aligned} \Delta G_a &= k_1 \cdot \max(0, EC - AO) \geq 0 \\ \Delta G_{oc} &= k_2 \cdot (MO - EC) \end{aligned} \qquad (10)$$

k_1 and k_2 are learning rate in amygdala and orbitofrontal units. As it was observed in recent equation, because of using MAX operator, the gain of amygdala’s unit is obligated to have an increasing univocal changes, it also has an accordance with a reality of physiology, which was surveyed in the previous paragraph, that according to it, amygdala’s unit not be able to forget what it learnt before. In the other words, desired work condition (which is reflected in high values of emotional signals EC) are caused gradually gain increasing of amygdala’s unit up to its physical maximum.

Now if in any reasons, those desired conditions change to undesired ones in future (with low value of emotional signal EC), amygdala’s unit won’t be able to indicate and modify this problem and will response like a desired condition.

So the gain of orbitofrontal unit is allowed to have negative/positive changes in order to modify the inappropriate answers of amygdala’s unit.

With combining (15) and (16) we have:

$$MO = (G_a - G_{oc}) \cdot SI \equiv G(SI, EC, \ldots) \cdot SI \qquad (11)$$

The most suitable suggestion for formulating the stimulation signal SI, is a PID shape format:

$$SI = k_P \cdot e_w + K_I \cdot \int_0^t e_w \, dt + K_D \cdot \dot{e}_w \qquad (12)$$

$$EC = a_{ec1} \cdot e_w + a_{ec2} \cdot MO + other\, terms\, (for\, other\, \mathrm{sec}\, ondary\, objectives) \qquad (13)$$

Where e_w is the error of closed loop system.

Fig. 3. Shows the block diagram of proposed controller.

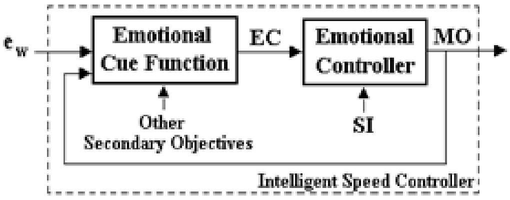

Fig. 3. block diagram of proposed controller

3. STABILITY ANALYSIS

In this part the quantitative-qualitative analysis of stability in closed loop control system will be discussed. With combination of (10) and (13) it will be:

$$\Delta G_{oc} = k_2 \cdot [(1-a_{ec2}) \cdot MO - a_{ec1} \cdot e_w] \quad (14)$$

Now with attention to the equations (11) and (14), the present of a positive feedback (the factor of stability in divergence form) in adjustment gin cycle G_{oc}, can be observed. The positive feedback will be obtained when the coefficient of $1-a_{ec2}$ is minus.

In small signal situation it can be assumed that:

$$\delta_{MO} \approx -\delta_{G_{oc}} \cdot SI \quad (15)$$

Also the form of small signal (14) is:

$$\delta_{\Delta G_{oc}} = k_2 \cdot [(1-a_{ec2}) \cdot \delta_{MO} - a_{ec1} \cdot \delta_{e_w}] \overset{\delta_{e_w} \approx 0}{\approx} k_2 \cdot (1-a_{ec2}) \cdot \delta_{MO} \quad (16)$$

With combination of two recent relations it will be:

$$\delta_{\Delta G_{oc}} \approx -k_2 \cdot (1-a_{ec2}) \cdot \delta_{G_{oc}} \cdot SI \quad (17)$$

If $\delta_{G_{oc}} \overset{\Delta}{=} y$, then with acceptable approximation, it will be $\delta_{\Delta G_{oc}} \approx \frac{dy}{dt}$ with rewriting equation (4-46) in order to recent definition it will be:

$$\frac{dy}{dt} + k_2 \cdot (1-a_{ec2}) \cdot SI \cdot y = 0 \quad (18)$$

And finally by using Laplace transform in recent equation, it will be:

$$Y(s) = \frac{1}{s + k_2 \cdot (1-a_{ec2}) \cdot SI} \quad (19)$$

Y(s) is the Laplace transform of small changes of gain G_{oc} and SI is a constant value. Now based on resulted small signal model and rest of equation, following results can be obtained:

1- Analytically (with regard to applied assumptions and also ideal performance of system different parts) if $a_{ec2}>1$, available feedback in internal loop of gain G_{oca} adjustment will be positive (in the other words the changes of G_{oc} and ΔG_{oc} will be aligned) so when $a_{ec2}=1$, dynamic Y has a pole in origin and it's ready for divergence and when $a_{ec2} >1$, dynamic Y has an unstable real pole and then Y and subsequently closed loop system will be unstable. It's important to say the created unstably (because of positivity of internal feedback in gin G_{oc} adjustment loop) can be omitted completely by using the gain limiters G_a and G_{oc} , however it mustn't be expected to have a desired performance in closed loop system.

2- It's better to choose the small and positive values of primary gain Ga and Goc values and it's allowed to emotional learning system to adjust properly their values in order to target purposes in emotional signal EC.

4. CONCLUSION

In this paper an analytical approach has been investigated. The quantitative-qualitative performed analysis are valuable for some following reasons: The determination of boundary stability of the structure coefficient of proposed emotional signal EC (because of proper first initialization and even searching desired adjustment mechanisms of emotional controller parameters).
Investigation and comparison of different proposal structures of emotional signal EC from two aspect of controller robustness (or extent of parameters boundary stability and subsequently the quality of transient and permanent behavior of controller close cycle system) and the manner of Accompanying with target secondary purposes.

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