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DESIGNING A FUZZY LOGIC CONTROLLER SYSTEM USING A HYBRID WQPSO-HB ALGORITHM

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Abstract : To optimize the settings of the fuzzy logic system, these works introduce the Hybrids Weighed Quantum Particle Swarm Optimization (WQPSO) – Honey Bee (HB) Operation, which incorporates the advantages of the WQPSO as well as HB. Although WQPSO could swiftly identify optimum solutions therefore to directed finding as well as data exchanges, HB does have a greater random factor, making it easier to avoid local optimal and discover outcomes globally. As a result, the Hybrids WQPSO-HB System can discover optimum solutions fast similar to WQPSO while also avoiding local optimal like HB. Simulations outcomes show the efficiency of the suggested method, as well as it's capacity to provide high-quality results that meet WQPSO as well as HB.

***IndexTerms* - Fuzzy Logic Controller; Hybrid WQPSO-HB Algorithm;**

1. Introduction

A fuzzy logic controller may be thought of as controlling intelligent systems that mimic human thought. It has membership functions for dependent and independent variables, as well as a collection of (IF...THEN) principles as well as supervised learning. The fuzzified controller is designed to entail selecting the operator's inputs & outputs variables, specifying membership functions parameters with each output and inputs parameters, establishing the rules Base to represent the lingual relationships between the input & outputs variables, including tuning the membership functions parameters plus scaling gains values to increase efficiency and effectiveness [1]. Those settings are generally chosen by trial - and - error while building fuzz regulators. That human construction process takes a long time to complete, as well as the control outcomes aren't ideal. Optimization algorithms are used to alter the settings of fuzzy systems to acquire the greatest plausible solutions according to a specific standard or utility function to address this difficulty [2].

Ever since the inception of fuzzy sets theories in 1965, several scholarly publications have just been presented by various researchers demonstrating its vast theoretical and practical implications. That approach, on the other hand, has indeed been mainly utilized for judgment, image recognition, pharmaceuticals, aviation, as well as, of necessity, improving traditional regulators & robotics [3]. As a result, its vast range of applications may be attributed to its ease of implementation, great flexibility, minimal susceptibility to systems oscillations, & lack the requirement for statistical equations [4]. Fuzzy logic is utilized in conjunction with other approaches in the papers researched, such as traditional PID regulators, slide modes, neural networks, robust control, fractional derivative converters, etc.

Every fuzzy logics controller is made up of 5 parts: fuzzifications, defuzzification, rules base, inference systems, as well as database servers. The issue of choosing a storage kind is among the most significant topics covered in this paper. [5] This collection contains information on memberships functions, identifiers, & subdomains. Because HBs describe the behavior of a physical variable, individuals must be selected proportionately to the variable's actual behavior. Triangle, trapezoids, sigmoidal, Gaussians, and bell-shaped patterns are among the most often utilized HBs. That the very first order mathematics capabilities of triangle & trapezoids functions make these straight as well as easy [6], which would be a significant benefit. 3 additional HBS, on either hand, have mild variations in form as well as provide greater precision for the fuzzified, although their non - linearity adds to the processing overhead. Nevertheless, for a fuzzy logic system to work well, all 5 of its components must always be chosen appropriately and precisely.

There is 2 type to the traditional method of selecting variables for a fuzzy logic system. Initially, a decision for fuzzy variables is determined based on the creator's past knowledge [7]. By inspecting the FIS outcomes in various operating settings, the original choice is improved significantly to achieve the desired effect of the fuzz monitoring systems. However, this method frequently encrypts in a local optimum but does not handle well enough in situations with many dimensionalities [8]. As a result, optimizations techniques that could also give great results in high-dimensional as well as multisensory functionalities, that are frequently employed, for this reason, are one of the finest processes for this challenge. This work seeks to examine the effectiveness of the fuzzy systems in robotics devices by considering the appropriate framework of the fuzzy systems as well as advanced analytics.

This bee colony technique has been widely used to improve fuzzy characteristics due to its durability and high effectiveness. Bee Colony Optimizations (BCO) is a meta-heuristic algorithm that shows the presence of nature-inspired methods [9-11]. Various environmental and physical phenomena have inspired various systems. Numerous human intelligence processes by machines have benefited from the use of ecological systems as inspirations and prototypes. [12] proposes a BCO approach for tuning the Mamdani style fuzzy operator's Membership Functions (HBs) for increased stability versus external forces. Triangle, trapezoid, as well as Gaussians HBs were compared in this study to controlling systems such as a water tanks system as well as some mobile robots. The high accuracy was found to be related to optimized triangle HBs in the interval of.

To modify the settings of a fuzzy logic system, several optimizing methodologies have been implemented. The researchers of [13] employed the Genetic Algorithms to fine-tune fuzzy controls rules. The researchers of [14] have shown that the PSO may control the premises as well as appropriate numbers of fuzzification concurrently for the proper design of fuzzy logic control. The Bees Algorithms was shown to be a valuable technique for adjusting fuzzy logic controllers to boost efficiency in [15]. Ant Colony Optimizations (ACO) are being used to construct an ACO-FC fuzzy controller in [16]. Solely on a single simulated instance, the suggested ACO-FC performed differently than traditional adaptive planning techniques. The Shuffled Frog Leaping Algorithms has been used in [17] to optimize the settings of a fuzzy logic controller that stabilized some beams systems at homeostasis. The developed control algorithm can manage the balls and beams combination itself around equilibrium position, as well as its efficiency, is superior to that of the well-known LQR regulator, according to simulated findings.

Scientists used the capabilities of these optimizations algorithms to create hybridization computers competent in looking for better alternatives possible to lessen time consumption and raise the efficiency of optimum solutions. For example, in [18], the researchers propose the WQPSO-GA hybridization method, which provides a combination of the WQPSO, such as data sharing between individuals in the organization, with a search engine that used a GA to assess the program outcomes. [19] suggested two hybridized Particle Swarm Optimizers that combined the particle swarms concept with elements from Adaptive Systems. Conventional speed and position updating criteria are combined with the concepts of propagation as well as subpopulations in hybridized PSOs. Combination techniques tend to create speed up as well as identify an ideal option, according to simulated data. In [20], the study presents HGAPSO, a hybridization method that integrates the novel individualized generating functions including both GA and PSO, simulating social behavior's, reproducing, and survivals of the fittest in creatures. The findings of FCRNN's periodic sequencing creation, as well as TRFN's dynamically plant control challenges, showed that HGAPSO outperformed GA with PSO.

Throughout this document, a hybrid method among both WQPSO as well as HB is proposed, that also manages to combine the abilities of WQPSO, such as the desire to detect optimized setting quickly, as well as HB, namely that the abilities to break free regionally optimizations algorithms, to tune fuzzy logic systems towards HB lancing flywheel inverse kinematics framework in the standing posture, and relates the abilities of such a combination optimization technique with WQPSO as well as HB.

2. Overview of WQPSO-HB Algorithm Optimization Techniques

Algorithms for Shuffled Frog Learnings (WQPSO) Its WQPSO is indeed a meta-heuristic optimizations approach that is inspired by the metaheuristic development of a bunch of frogs searching for the most meal. Locals search, as well as worldwide data sharing, are both incorporated into the algorithms. The WQPSO is made up of a population of alternatives specified by a group of digital frogs that is divided into memeplexes. Single frogs inside memeplexes have thoughts that may be impacted by the thoughts of many other frogs, and all these thoughts could develop throughout a metaheuristic evolutionary line. That used a particles swarm's optimizations-like technique, the WQPSO does a locally owned searching within every memeplex at the same time. To guarantee worldwide investigation, the digital frogs were scrambled & rearranged into newer memeplexes until a certain amount of memeplex evolutionary stages (i.e. locals searching rounds) using a process similar to the scrambled complicated evolutionary method. The WQPSO's workflow is seen in Figure 1.

Updated Frog Leaping rule is defined as:

$$E = s.d(X_c - X_y) \quad (1)$$

$$X_y(new\_one) = X_y + E \quad (2)$$

Where,

X_c, X_y is the best and worst updated position of frog respectively;

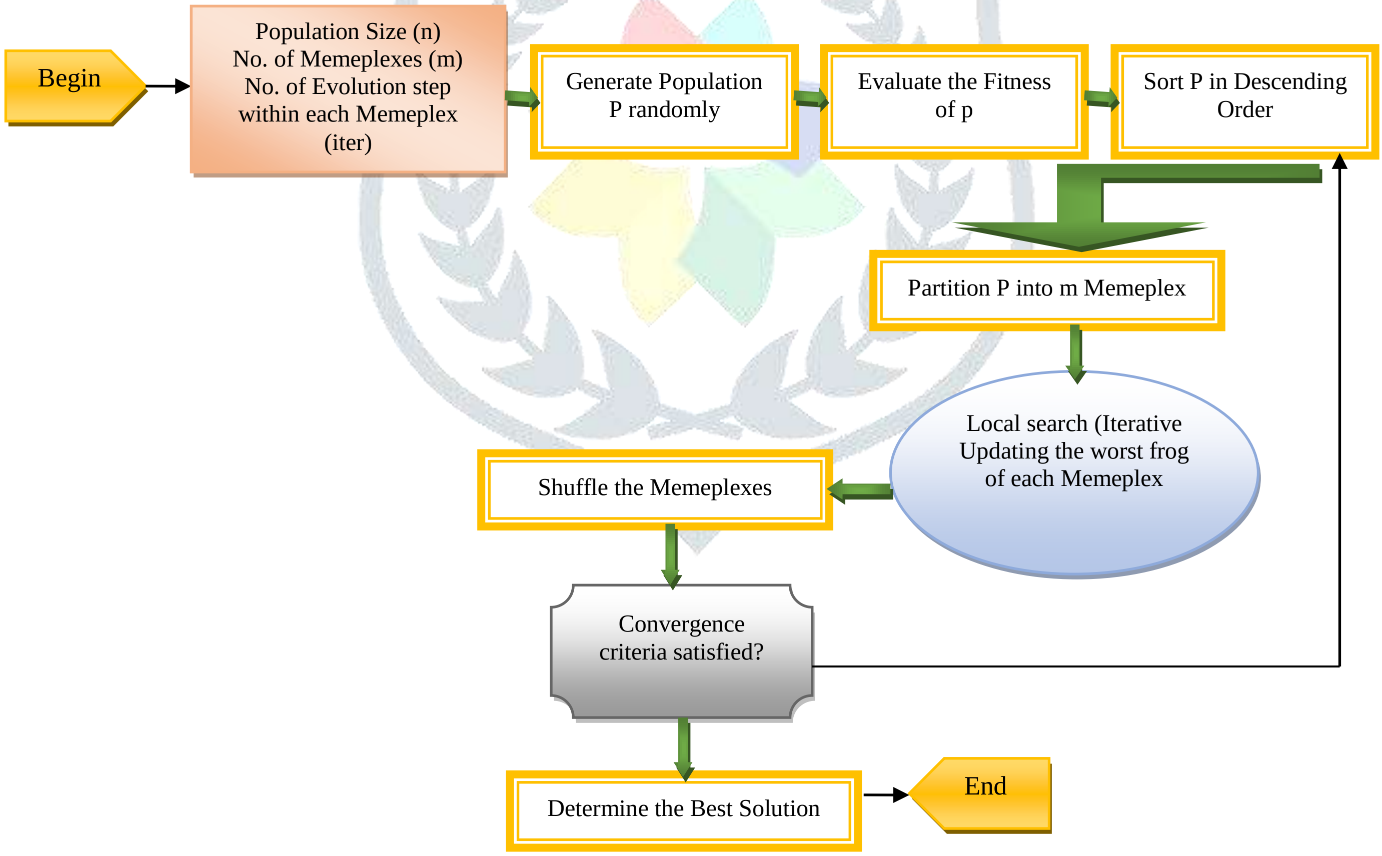
s - random numbers in between 0 to 1.

d- constant ranges between 0 to 2.

This Bees Technique is an optimization technique that relies on honey bee foraging behavior to identify the best solution. The n scouting honeybees are placed randomly in the searching space to begin the procedure. These scouting honeybees visiting areas are assessed for their competence. These fittest honeybees are picked as "chosen honeybees," as well as the areas they explore were selected for neighborhood searches. This algorithm next performs searching in the vicinity of the chosen locations, sending extra honeybees to seek in the vicinity of the top e locations. Such honeybees can be selected based on their efficiency and the wellness of the locations regularly frequent. The HB's workflow is depicted in Figure 1.

Every memeplex grows separately in the SFL algorithms to selectively explore various portions of the solution space. The memeplexes were therefore mixed as well as re-divided into the fresh memeplexes to carry out a global searching via exchanging data.

$0 \rightarrow D \Rightarrow Xb) \rightarrow Xb$ ($Xw \rightarrow$ when $Xw \Rightarrow$From equation (1) Xb, i.e, when variance in position$\rightarrow Xw(new) = Xw \Rightarrow$ between Xw and Xb (Xg) becomes tiny, This difference in frog Xw(new) location is modest, trapping the method in a local optimum as well as causing convergence speed. Additionally, this greatest frog's data is only utilized once in each updating. The knowledge produced excellent honeybees (Excellent Websites) is used numerous times in the Bees Algorithms, and the leftover honeybees in the community would be substituted by randomized honeybees.



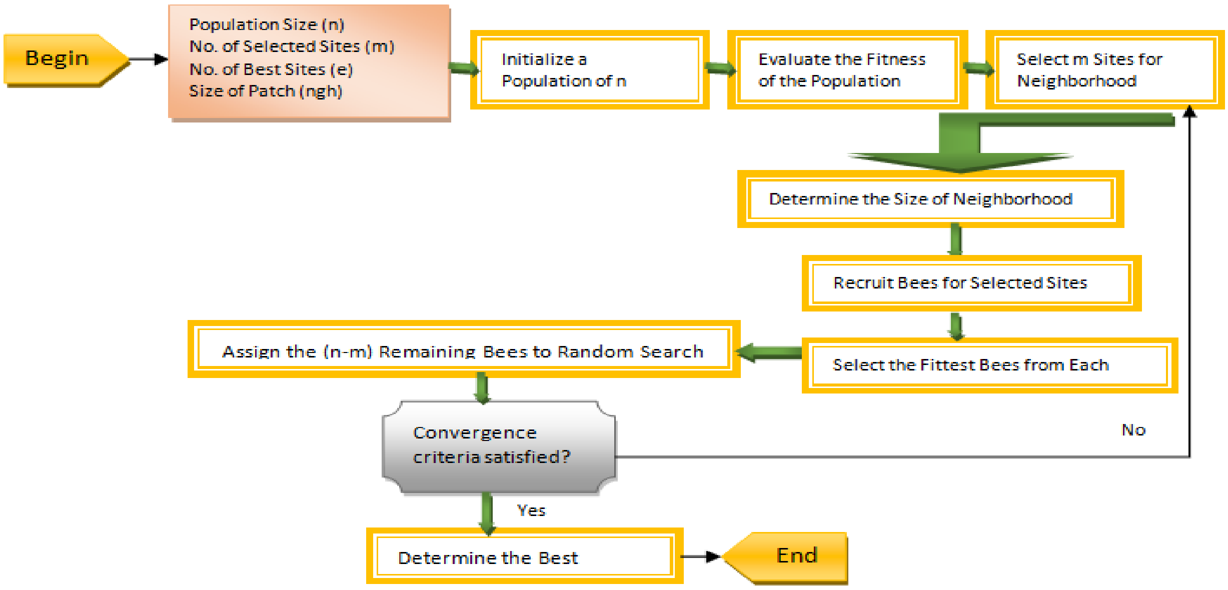


Fig. 1 Flowchart of the WQPSO and HB

By contrast to WQPSO, HB attempts to "squeeze" from around the location of nice honeybees numerous times. As a result, HB can locate solutions of superior qualities, but the searching time is prolonged. WQPSO, on the other hand, can identify a resolution rapidly by integrating global and regional exploring. Following finishing a production of WQPSO, a Hybrids WQPSO-HB Mechanism may be generated as follows: once finishing production of WQPSO, HB would be employed with some small alterations. When HB upgrades their trainees, m of the finest honeybees will be changed by randomized honeybees, as well as m of the worst honeybees would be substituted by the randomized honey bee. Figure 2 illustrates the structure of the Hybrids WQPSO-HB

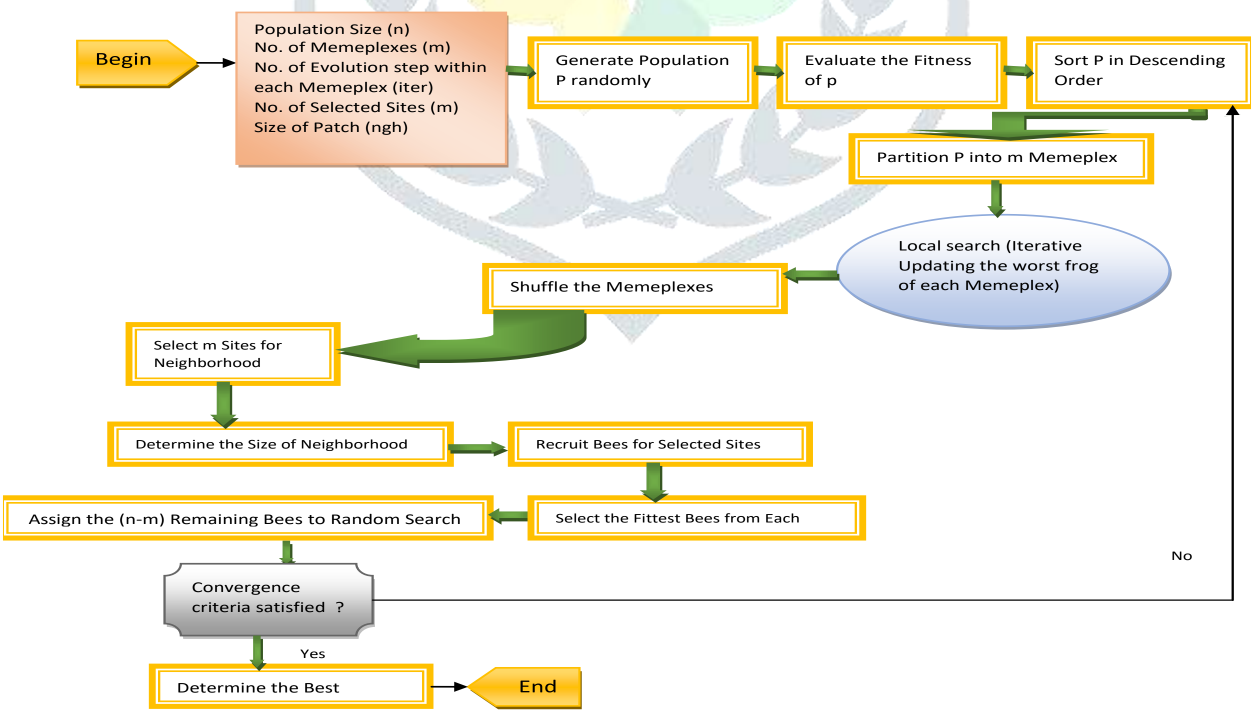


Fig. 2 Workflow for the Hybrid WQPSO/HB

3. Fuzzy Logic Control Design

This chapter explained well how to create a fuzzy logic controller using the Hybrids WQPSO-HB Algorithms to balance a rotating inverting pendulum in the uprights posture. Figure 3 depicts the controls system's block diagrams. The linguistics values of such outcomes were conditioned by singleton memberships functions in the [-1, 1] world of discussion, as shown in Figure 4. Both memberships functions NE, as well as PO in the inputs, are symmetrical around 0. Likewise, the memberships functions Nj&Pj in the outputs were symmetrical. This amount of modifiable variables is minimized by constructing symmetrical memberships functions. As an outcome, this optimizing issue that will be tackled afterward will be better at solving. The suggested fuzzy logics controller's HB is based on the Sugeno paradigm. This ruling Base is made up of 81 (IF...THEN) principles that have been developed from humans' comprehension. Table 1 contains the whole decision rules. Concepts for a rule-based architecture. The very next stage is to optimize the fuzzy operator's settings following developing its architecture related to human understanding.

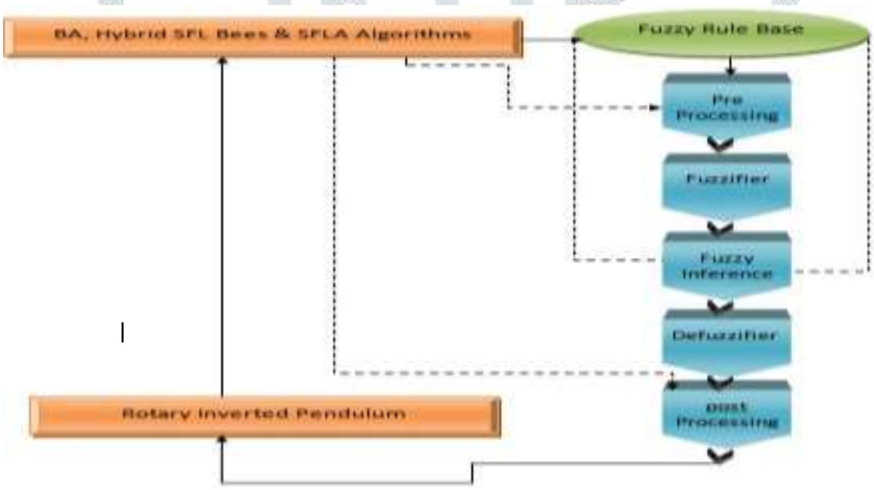
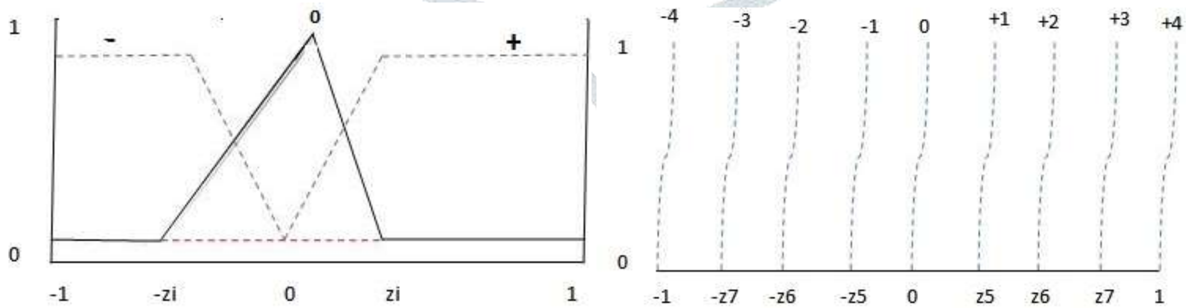


Figure 3: Fuzzy Logic Controller Parameters



(a) (b)

Figure 4: (a&b) Input and Output membership functions, respectively

TABLE I. Rule-Based Method

#	θ	α	$\dot{\theta}$	$\dot{\alpha}$	u	#	θ	α	$\dot{\theta}$	$\dot{\alpha}$	u
1	NE	NE	NE	NE	P1	42	ZE	ZE	ZE	PO	P1
2	NE	NE	NE	ZE	P2	43	ZE	ZE	PO	NE	N2
3	NE	NE	NE	PO	P3	44	ZE	ZE	PO	ZE	N1
4	NE	NE	ZE	NE	ZE	45	ZE	ZE	PO	PO	ZE
5	NE	NE	ZE	ZE	P1	46	ZE	PO	NE	NE	P1
6	NE	NE	ZE	PO	P2	47	ZE	PO	NE	ZE	P2
7	NE	NE	PO	NE	ZE	48	ZE	PO	NE	PO	P3
8	NE	NE	PO	ZE	P1	49	ZE	PO	ZE	NE	ZE
9	NE	NE	PO	PO	P2	50	ZE	PO	ZE	ZE	P1
10	NE	ZE	NE	NE	P2	51	ZE	PO	ZE	PO	P2
11	NE	ZE	NE	ZE	P3	52	ZE	PO	PO	NE	N1
12	NE	ZE	NE	PO	P4	53	ZE	PO	PO	ZE	ZE
13	NE	ZE	ZE	NE	P1	54	ZE	PO	PO	PO	P1
14	NE	ZE	ZE	ZE	P2	55	PO	NE	NE	NE	N4
15	NE	ZE	ZE	PO	P3	56	PO	NE	NE	ZE	N3
16	NE	ZE	PO	NE	ZE	57	PO	NE	NE	PO	N2
17	NE	ZE	PO	ZE	P1	58	PO	NE	ZE	NE	N4
18	NE	ZE	PO	PO	P2	59	PO	NE	ZE	ZE	N3
19	NE	PO	NE	NE	P2	60	PO	NE	ZE	PO	N2
20	NE	PO	NE	ZE	P3	61	PO	NE	PO	NE	N4
21	NE	PO	NE	PO	P4	62	PO	NE	PO	ZE	N3
22	NE	PO	ZE	NE	P2	63	PO	NE	PO	PO	N2
23	NE	PO	ZE	ZE	P3	64	PO	ZE	NE	NE	N2
24	NE	PO	ZE	PO	P4	65	PO	ZE	NE	ZE	N1
25	NE	PO	PO	NE	P2	66	PO	ZE	NE	PO	ZE
26	NE	PO	PO	ZE	P3	67	PO	ZE	ZE	NE	N3
27	NE	PO	PO	PO	P4	68	PO	ZE	ZE	ZE	N2
28	ZE	NE	NE	NE	N1	69	PO	ZE	ZE	PO	N1
29	ZE	NE	NE	ZE	ZE	70	PO	ZE	PO	NE	N4
30	ZE	NE	NE	PO	P1	71	PO	ZE	PO	ZE	N3
31	ZE	NE	ZE	NE	N2	72	PO	ZE	PO	PO	N2
32	ZE	NE	ZE	ZE	N1	73	PO	PO	NE	NE	N2
33	ZE	NE	ZE	PO	ZE	74	PO	PO	NE	ZE	N1
34	ZE	NE	PO	NE	N3	75	PO	PO	NE	PO	ZE
35	ZE	NE	PO	ZE	N2	76	PO	PO	ZE	NE	N2
36	ZE	NE	PO	PO	N1	77	PO	PO	ZE	ZE	N1
37	ZE	ZE	NE	NE	ZE	78	PO	PO	ZE	PO	ZE
38	ZE	ZE	NE	ZE	P1	79	PO	PO	PO	NE	N3
39	ZE	ZE	NE	PO	P2	80	PO	PO	PO	ZE	N2
40	ZE	ZE	ZE	NE	N1	81	PO	PO	PO	PO	N1
41	ZE	ZE	ZE	ZE	ZE						

These inputs memberships functions parameters, the outputs memberships function variables (refer Fig. 4), as well as the scalability benefits (refer Figure 5) are the variables to be optimized. This fuzz operator's parameters were determined using the quadratics criteria (3), using positively definite weighted matrix Q & R.

To handle this optimal control problem, the WQPSO, HB, or Hybrids WQPSO-HB Algorithms are used.

4. Results and Discussions

Either WQPSO, HB, / Hybrids WQPSO-HB Mechanism Basis fuzz controllers is implemented using Matlab as well as Simulink. Figure 5 shows a simulation of a rotating inverted pendulum.

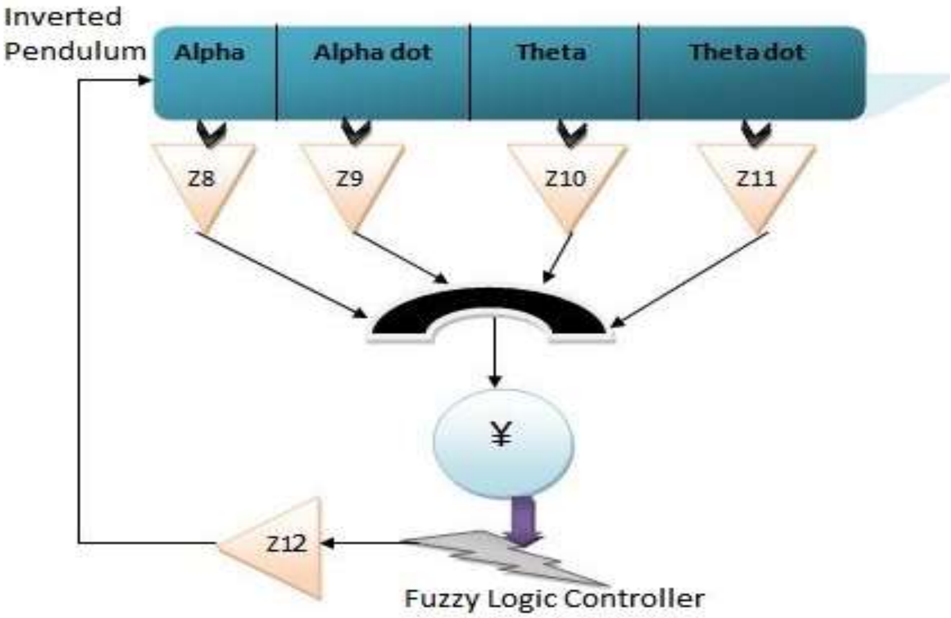


Figure 5 Rotate invert pendulum Simulation diagram

There are 12 parameters in FLC which need to be tweaked, ranging from X1 to X12. Table 2 lists the WQPSO, HB, as well as Hybrids SFL-HB characteristics. The following settings have been selected. Regarded as the best outcomes of several experiments. Throughout a "trial-and-error" procedure, the weighted matrix.

Table 2: The WQPSO, HB, and Hybrid WQPSO-HB parameters

	N	H	d	l	iteration	d	X1	X2	GH
WQPSO	70	650	4	20	20				
HB	70	650		25		6	20	30	0.20
WQPSO-HB	70	650	4	20	20	6	20	30	0.20

Figure 6 shows the evolutions of the quadratics performance indexes. Closed systems reply when utilizing WQPSO, as seen in Fig. 7.

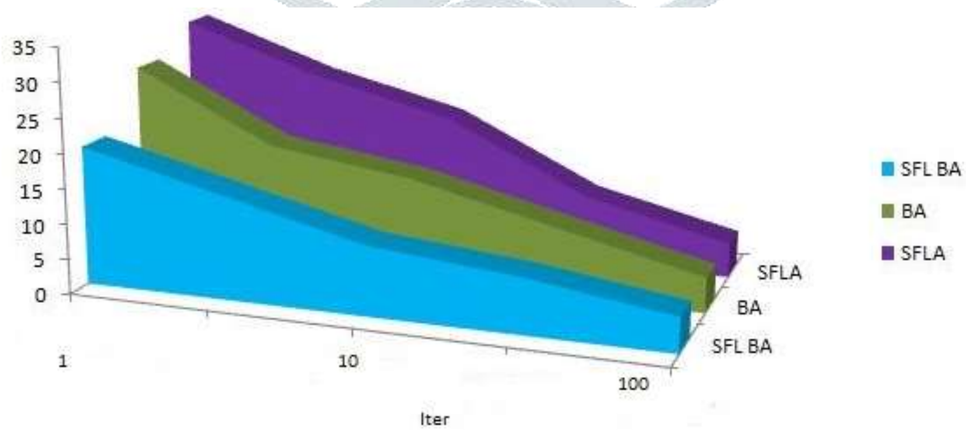


Fig. 6 Evolution of index

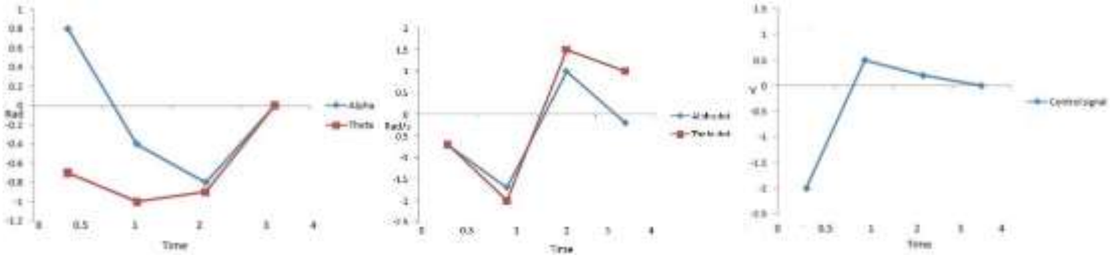


Fig. 7 Closed response of the system

This same concurrent percentage of the Hybrids WQPSO-HB Technique is quicker than those of the HB (comparable to those of WQPSO), whereas the objectively function values (index) of the Hybrids WQPSO-HB Method is larger than those of the HB and though narrower than that of WQPSO (Hybrids WQPSO-HB Method has the resilience of the HB., i.e. must be capable of conducting a globally searching for solutions)

5. Conclusions

The Hybrids WQPSO-HB Method is introduced in this study as some revolutionary algorithms that incorporate the characteristics of WQPSO plus HB, notably the capability to swiftly discover the global optimal solutions. The FLC characteristics are tuned using the WQPSO, HB, as well as Hybrids WQPSO-HB Algorithms. ultimately, the findings show that such methods may be utilized to optimize the settings of a fuzz logic system in order to stable a rotating inverted pendulum mechanism inside its upward equilibriums position. It could be said that the Hybrids WQPSO-HB Algorithms are comparable to the WQPSO method in terms of convergence rates, and both are quicker than HB. Furthermore, as compared to WQPSO, the Hybrids WQPSO-HB Algorithms & HB provide lower objectives function values.

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