Performance Evaluation of Mobile Intelligent Poultry Liquid Feed Dispensing System Using Two-Way Controller Technique

[1]O.M. Olaniyi, [2]T.A. Folorunso [1]E.M. Dogo, [2]M.E. Bima & [1]A. Adejumo
[1]Department of Computer Engineering, Federal University of Technology Minna, Nigeria
[2]Department of Mechatronics Engineering, Federal university of Technology Minna, Nigeria
{mikail.olaniyi; funso.taliha; eustace.dogo; bimamuhammad}@ futminna.edu.ng; adejumoabidemi246@gmail.com

Abstract
Many automated liquid feed dispensing systems have problems with long response time which had resulted to overall poor performance of the system. In this paper, we present the performance evaluation of a mobile intelligent poultry liquid feed dispensing system using a two-way controller approach by adopting Genetic Algorithm tuned PI controller and Internal Model Controller (IMC). The performance of the dispensing system and the controller was evaluated using transient responses and Integral Average Error (IAE) metric respectively. The results obtained from the application of the GA tuned PI tuned controller to the system shows an improvement in terms of the transient response and also in terms of IAE controller evaluation. However, the system suffers a slight overshoot of about 4%. The application of IMC controller showed an improvement in terms of the zero overshoot and a slightly high IAE as compared to the GA tuned PI controller. This shows that GA tuned PI tuned controller has a significant performance improvement on the system for better return of investment, reduced human involvement and dispensation of uncontaminated liquid feed to birds in deep litter poultry system.

Keywords— PI controller, Internal Model Control (IMC), Genetic Algorithm, Integral Absolute Error (IAE).

1. INTRODUCTION

Intelligent Poultry feed dispensing systems are intelligent mechatronics systems designed to mimic the human poultry farmer in dispensing feeds to birds at specific time intervals. This system is designed to reduce to barest minimum high level of human involvement in poultry feeding, reduce time and feed wastages and prevent infections and diseases to poultry birds (Arulogun, Olaniyi, Oke, and Fenwa, 2010). Numerous feed dispensing systems designed to provide this advantages in poultry feed management in tropics are presented in literature in (Adedinsewo, 2004; Arulogun, *et al.* 2010; Olaniyi, Salami, Ahmed, & Adewumi, 2013, Olaniyi, Salami, Adewumi, Ajibola, 2014; Adewumi, 2014 and Olaniyi, Folorunso, Akogbe, Adejumo, 2015.)

However, these poultry feed dispensing systems design in literature had problems of pulsation; due to their inherit instability. Furthermore, this requires the need for controller systems such as the Proportional Integrative Derivative (PID) and Internal Model Control (IMC) Controllers to help achieve stability and in most cases excellently reduce the pulsation behavior of the existing feed dispensing systems. In Olaniyi, *et al.* (2015), a Ziegler-Nichols (ZN) tuned PID Controller mobile poultry liquid feed dispensing system was designed to provide stable system to reduced human labour involvement in poultry liquid feeding, poultry liquid feed poisoning and low production yield in poultry management. Although the ZN tuned PID systems were proven to require less training, have online options, provided "quick –dirty" approach to controller designs and are applicable to system design when the state properties of system are unknown; they lacked robustness and required too little processing information when used for closed loop design system (Costa, 2011).

In view of these limitations of ZN Controller tuning, we propose a two-way controller approach to actually determine the most suitable controller type for the designed poultry dispensing system. We further adopted the use of a Genetic Algorithm based optimization technique in the determination of the PID controller parameters. Thereafter in the quest to evaluate the effectiveness of other type of controller on the system, the IMC controller type was used on the designed poultry dispensing system. The evaluation of these controllers shows promising and excellent results in achieving good system response in the attainment of overall stability at a very reasonable time. Thus, achieving a reliable and well controlled intelligent poultry feed dispensing system.

The remaining part of this work is divided into four (4) sections. In section 2 a detailed review of related works are presented. The system design discussed in section 3 put into consideration the system model, controller design as well as hardware design consideration of the system. Thereafter the results and discussion are presented in Section 4 and the work was concluded in section 5.

2. REVIEW OF RELATED WORKS

A number of related works exists in literature in application of intelligent system to poultry feed dispensing systems. Olaniyi *et al.,* (2013) designed an intelligent poultry water dispensing system using fuzzy logic control technique. The strength of this work was that the system could intelligently dispense water based on observed parameters of poultry liquid feeding. Some of the limitations of the system were: the system was static, therefore it could not move from one point to the other. The system could not feed large number of poultry birds and laborious involving high human involvement. The designed system in Olaniyi *et al.,* (2013) was developed by Adewumi (2014). The system could intelligently dispense liquid feed. Some of the limitations of the developed system in Adewumi (2014) were possibility for liquid feed poisoning, inability to move and feed large number of birds.

These limitations were solved in Olaniyi, *et al.* (2015) through application of ZN technique in tuning a PID Controller for the liquid feed dispensing system. The designed system was mobile and provides better rise and settling time compared to similar system without PID controller. However, the system lack robustness and the rise time as well the settling time is high. Therefore, better liquid feed dispensing system could be developed with a shorter settling time and rise time if intelligent software PID controller is incorporated to control the system.

Preference for PID over fuzzy logic technique was justified over a comparison of study between PID controller and Fuzzy logic controller to control a DC motor in Adewuyi (2013). However, the comparison was not based on a poultry dispensing system but the combination of PID and Fuzzy logic controllers on the system model shows the that PID controller possessed better performance in terms of the system's rise time and settling time than the Fuzzy controller. Genetic Algorithm based parameter tuning of PID controller for composite control was carried out in Tandon & Kaur (2011). ZN techniques for PID controller and GA techniques for tuning PID controller were compared for composite control. The output performance on their system model shows that ZN method does not provide adequate tuning parameters as compared to the intelligent Genetic Algorithm optimization approach.

Based on the aforementioned, this paper in quest of our anticipation in Olaniyi, *et al.* (2015) attempted to solve the above limitations of the feed dispensing systems by the integration of a two controllers approach namely a Genetic Algorithm tuned PI controller as well as a IMC controller in quest to determine the most efficient and effective controller for the mobile poultry liquid feed dispensing system.

3. SYSTEM DESIGN

This section presents the system design of the mobile intelligent poultry liquid feed dispensing system in details putting into consideration the system model, the controller design and its parameters as well as the hardware requirements. The schematic diagram of the mobile Intelligent poultry feed dispensing system is as depicted in Figure 1. This system is as presented in Olaniyi, et al.(2015) showing the main components namely the trough, control unit module, Wheels for mobility as well as the drinker.
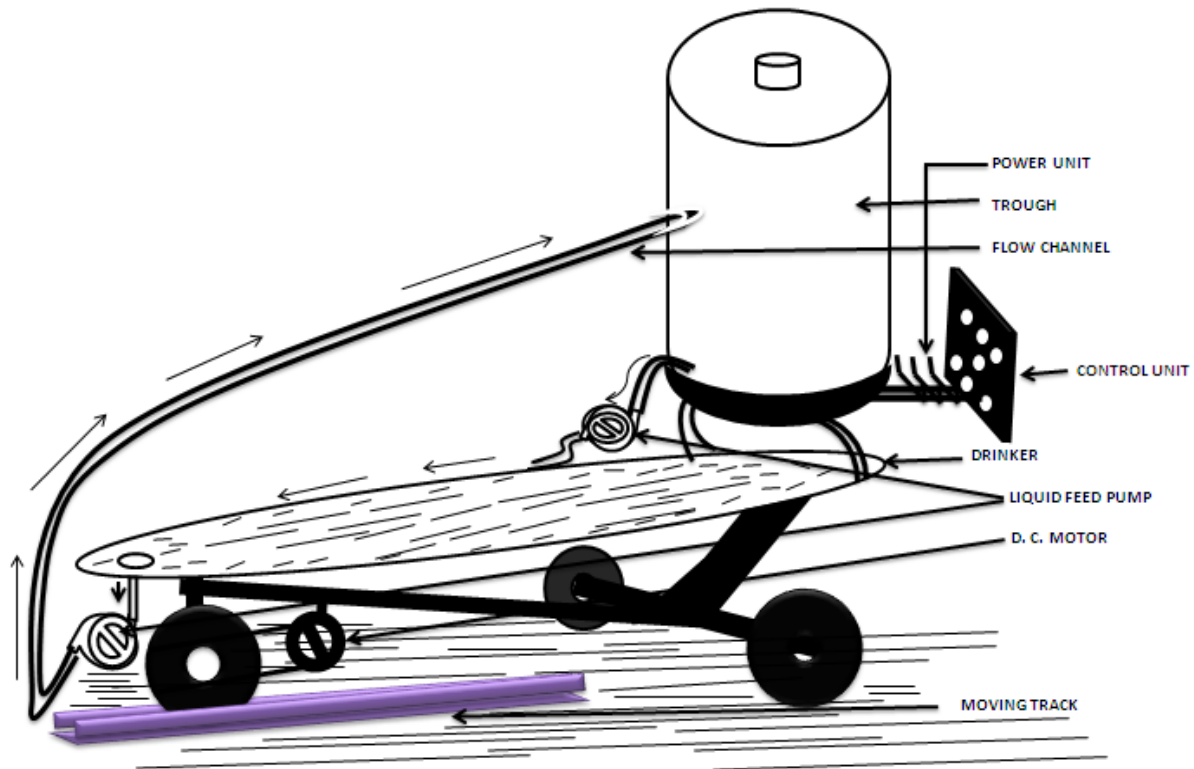
Figure 1: Mobile intelligent poultry liquid feed dispensing system. (Olaniyi, et al. 2015)

Basically, in actualizing the schematics as depicted above the entire system is subdivided into modules or subsystems. In Figure 2, the block diagram of the various subsystems required for the formation of the system is shown. The subsystems includes, power supply unit (required for supply of the required voltage to all other unit), mechanical unit (Wheels and other rotatory elements) and liquid dispensing unit (liquid feed pumps). The Microcontroller Unit (MCU) serves as the brain of the system as it controls the operation of all other subsystems of the Dispensing system.
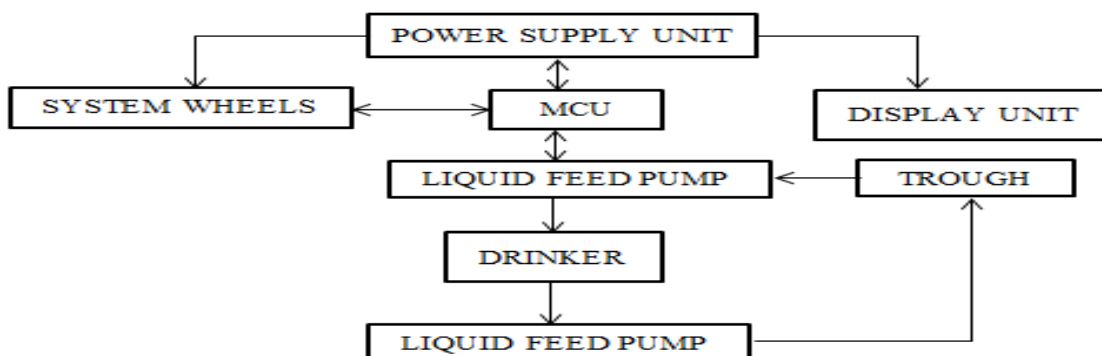

Figure 2: Interconnection of the Subsystem of proposed Dispensing system

3.1 System Mathematical Model

The mathematical model of the system relating the input and output of the system together is as presented in Equation 3.1. The obtained model in terms of the transfer function as presented in Olaniyi, *et al.* (2015) relates the input of the liquid feed into the trough and the corresponding voltage applied to the feed pump. This is to ensure that the control of the liquid feed level in the trough at all times so as to ensure constant availability to avoid excessive or limited supply and also timely movement of the system. The proposed controllers design is based on the developed transfer function representing the system.

$$G(s) = \frac{8.5}{s + 0.07142}$$

(3.1)

3.2 Controller design

In this paper, the performance of two controllers namely the Genetic Algorithm Tuned PI controller and the IMC controller was investigated based on the developed system model. As a requirement for design, the controller should be able to satisfy a system requirement of a situated rise and settling time and a very minimal overshoot. The detail of each controller design is as follows:

3.2.1 Genetic Algorithm Tuned PI Controller

Genetic Algorithm (GA) principles were first proposed by John Holland in the 1960s. GA is an intelligent optimization technique based on the concept of natural selection, evolution and genetics. The fundamental concept behind the GA is to model a problem in a natural way such that the Charles Darwin's concept of selection alongside other evolutionary processes can be applied to produce solution for the problem that is better than their previous solution. Its usage solving difficult search and optimization problem has proven to be quick, reliable, effective and efficient (Gen and Cheng, 2000).

The three major operators of GA are selection, crossover (or recombination) and mutation. The control parameters are the population size, selection, crossover and mutation (Srivinas, Lakshmi & kumar, 2013). The selection operator selects chromosomes in the population that will be allowed to reproduce and the fitter chromosome performs better than the less fit ones by producing more offspring. A chromosome is more likely to be selected if discovered to be fitter to reproduce. The crossover operator enables the exchange of subparts of the chromosomes, which mimics the recombination process between two-single chromosomes (haploid) organisms biologically. Mutation operator changes the values of allele randomly of some location in the chromosomes (Srivinas, Lakshmi & kumar, 2013).

The flowchart in Figure 3 depicts the various stages of the GA process, while Table 1 shows the GA parameters used and result obtained for this work. Consequently, an interesting point to note in the flowchart is the inclusion of a repair strategy (Folorunso and Ismail, 2013) which occurs after the crossover and mutation process. Basically the essence is to check for offspring's which after the process of mutation that does not satisfy the constraint of the problem any longer. If any offspring is found, they are discarded and the entire process of crossover and mutation is repeated for the parents forming the discarded offspring. At the end of the repair strategy, the new offspring are placed in the next generation population. The repair strategy alongside the Elitism are mechanisms put in place to ensure the fidelity of the result obtained and also ensures that potentially good chromosome which are possible solutions to the problem are not discarded too early in the iteration of the genetic algorithm (Folorunso and Ismail , 2013).

TABLE I. GENETIC ALOGRITHM PARAMETERSS

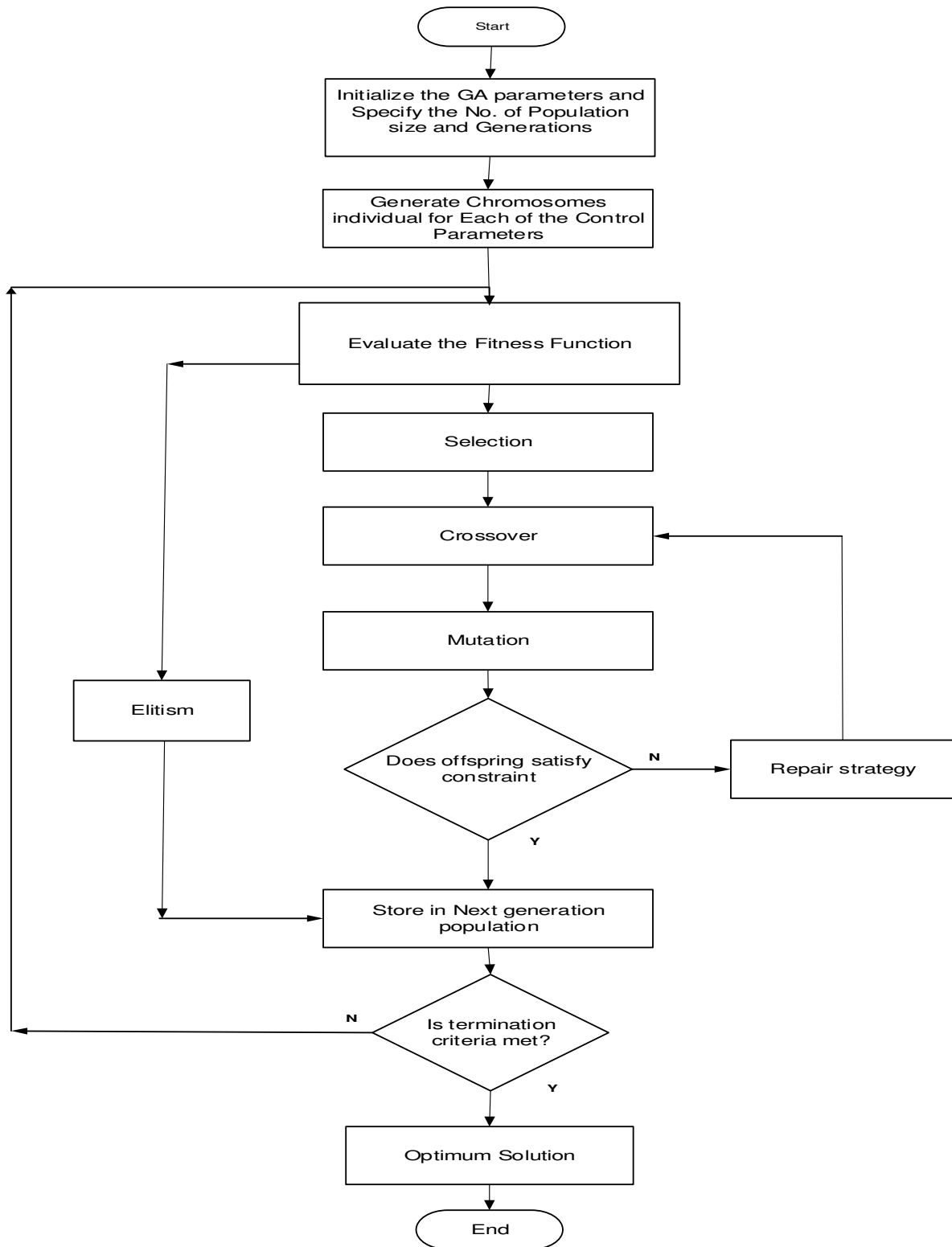| S/N	Model Parameters	
	Parameter Description	*Values*
1	Number of population	100
2	Number of Generations	100
3	Elite count	2
4	Mutation rate	0.05
5	Crossover rate	0.9
6	Selection type	Roulette Wheel
7	Obtained Kp Parameter	1.554
8	Obtained Ki Parameter	0.523

Figure 3: The Adopted Genetic Algorithm Flowchart

3.2.2 Internal Model Controller (IMC)

The Internal Model Controller (IMC) is another very effective method of control as it adopts the process model for feedback control. One characteristic advantage of this controller technique is that it uses the process model directly and requires limited computations. The IMC uses the process model and inverts parts of the model for use as a controller for the process (Folorunso *et al*, 2013). Conversely, not all parts of the model are invertible such as the delay and the right half plane poles. Hence in such model where such exist, a linear filter (Eqn 2) is often included and the tuning of the filter influences as well as determines the performance of the IMC Controller (Rivera, Morari, & Skogestad 1986)

$$G_f(s) = \frac{1}{[\lambda_f s + 1]^n} \qquad (Eqn\ 2)$$

Where λ_f the filter parameter and n is is the order of the filter.

The structure of the IMC Controller is as presented in Figure 4 $G_p(s)$ is the system model, $G_m(s)$ is the process model which is used in the controller design and $G_{IMC}(s)$ is the IMC controller.
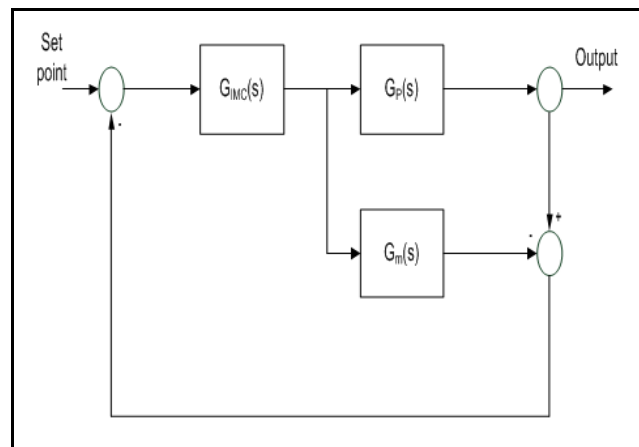

Figure 4: Structure of the adopted Internal Model Controller (IMC)

The IMC Controller $G_{IMC}(s)$ which is the main controller of the system is derived by breaking down the Model process (same as the system model) $G_m(s)$ into invertible, $G_m^-(s)$ and non-invertible, $G_m^+(s)$ parts:

$$G_m(s) = G_m^+(s) * G_m^-(s) \qquad (Eqn\ 3)$$

The system model $G(s)$ is a first order system without delay/dead time, hence the non-invertible part $G_m^+(s)$ will be eliminated as it could leads to instability issues if inverted therefore taking into consideration only the invertible part $G_m^-(s)$ which is stable and causal (Rivera 1999, Folorunso *et al* 2013). The controller $G_c(s)$ is set to be equal to the inverse of the invertible part as:

$$G_c(s) = [G_m^-(s)]^{-1} \qquad (Eqn\ 4)$$

Furthermore to attain reliability, robustness and increase in system performance, the filter $G_f(s)$ with tunable parameter λ_f is added to the $G_c(s)$. The filter also ensures that the system is stable at all times.

$$G_{IMC}(s) = G_C(s) * G_f(s) \qquad (Eqn\ 5)$$

As a rule of thumb, the filter parameter λ_f is selected to be at least twice as fast as the open loop response of the process model $G_p(s)$. Using this as an initial value for the filter parameter and continuously tuning it till when a desirable optimal response is obtained at $\lambda_f = 1$. With that, the overall IMC controller is given as:

$$G_{IMC}(s) = \frac{s + 0.07142}{8.5s + 8.5} \qquad (Eqn\ 6)$$

4. RESULT AND DISCUSSION

This section discusses the results obtained from design GA tuned PI Controller as well as the IMC controller. In Figure 5, the Matlab/Simulink of the developed System feedback control showing the GA tuned PI controller at the top and that of the IMC controller at the bottom.
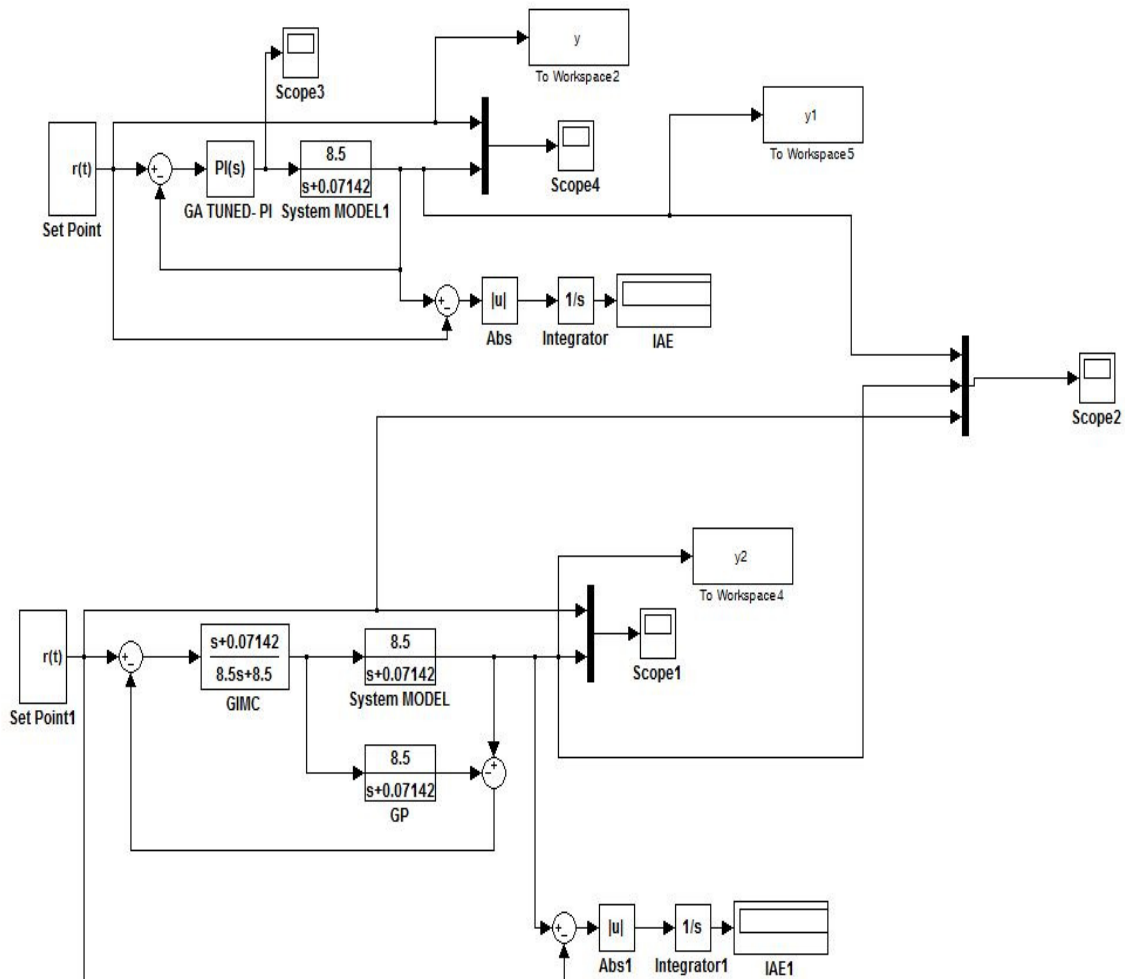

**Figure 5: The Simulink Design of System Controller**

The Figures 6,7,8,9 show the responses of the open loop system, the GA Tuned PI Controller, the IMC controller and the comparison of the GA –PI and the IMC controllers respectively. Basically, it is eminent from the open loop response in Figure 6 that there is a significantly high and unwanted system over shoot which is undesirable for any system as well as the poultry feed dispensing system, hence the need for a controller to improve the performance of the response.
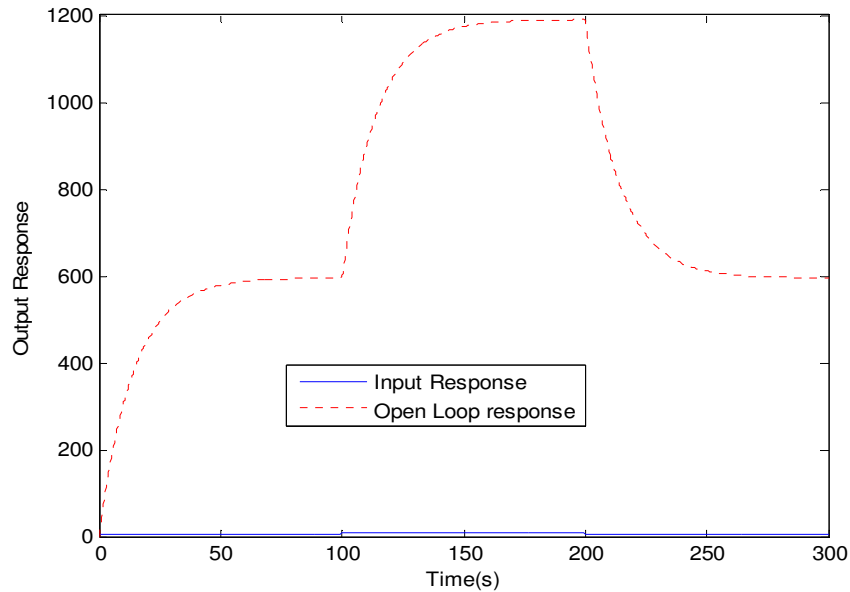
Figure 6: The Open Loop Response of the System

However, with the introduction of the GA-Tuned PI controller there is a significant improvement in the system response, in terms of its Rise time, settling time and the overall system overshoot as compared to the open loop response. The GA- Tuned PI Controller enjoys very high rise time of about 0.1secs and the good settling time of 3.8secs giving the system an improved performance over the open loop response as depicted in figure 7
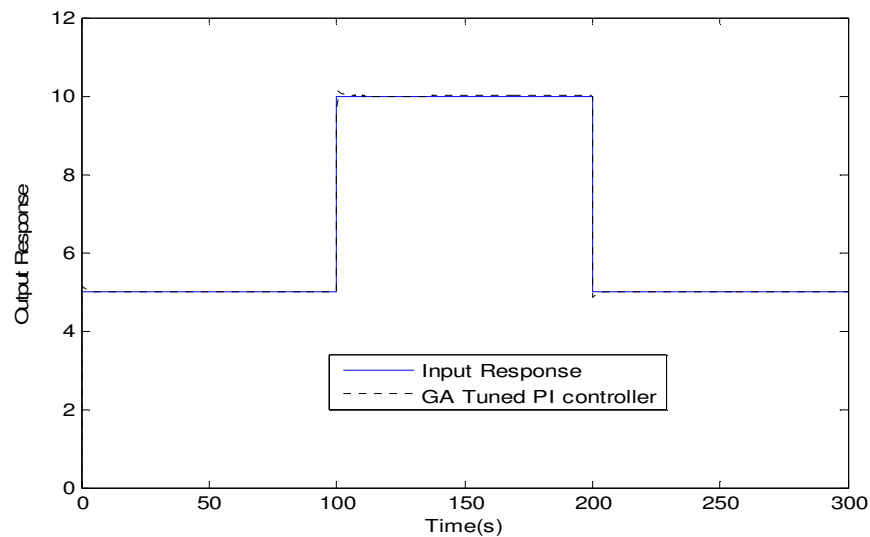
Figure 7: Response of the GA Tuned PI Controller

Consequently, the GA-PI Tuned Controller form Figure 7 has a slight overshoot of about 4% which is considerably better when compared with the open loop. With the introduction of the IMC Controller, the overshoot of the system is being eliminated as depicted in Figure 8. Furthermore, it was observed that the rise time and the settling time is considerably increased as compared to the GA-Tuned PI Controller.
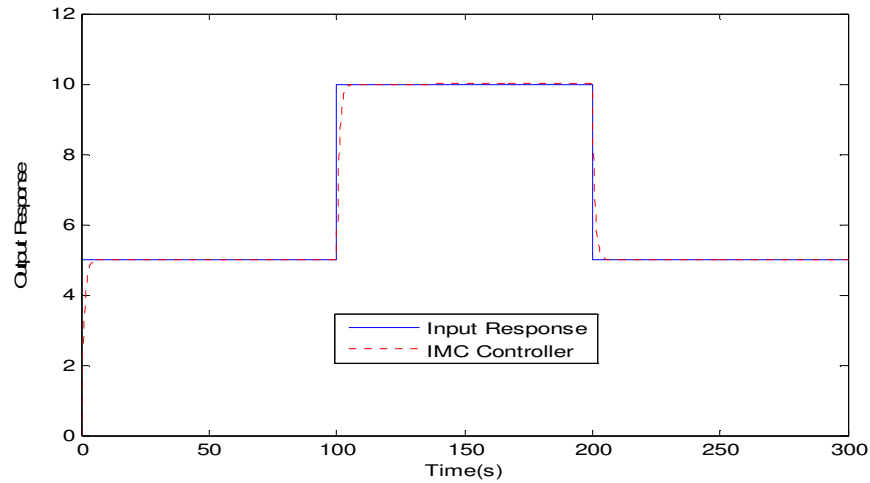

Figure 8: Response of the IMC Controller

A Comparison of the GA-Tuned PI and IMC controller is presented in figure 9 and the transient characteristics of both controllers is presented in Table II. One characteristic feature of both controllers response shows a zero steady state error meaning fluctuation of the system over a long time of operation, thus making the intelligent poultry system stable and controllable over a long time.
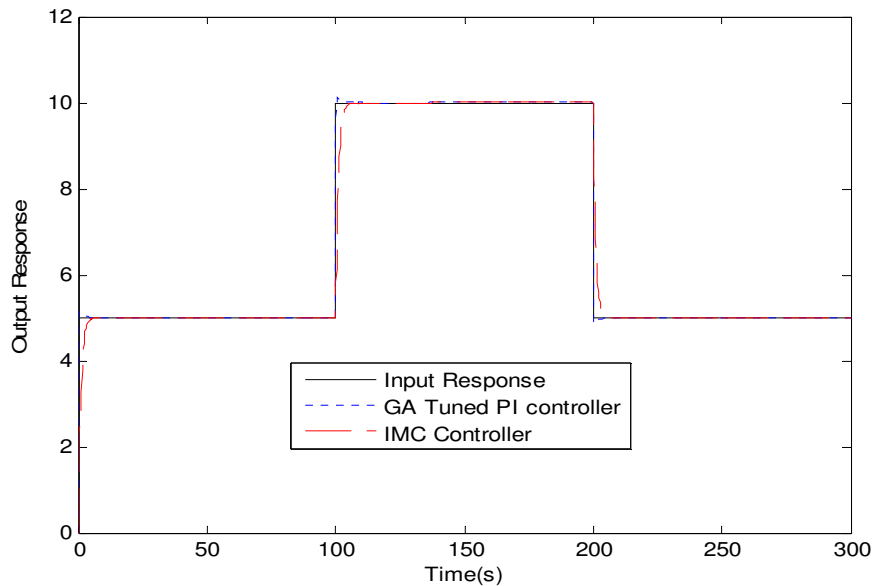

Figure 9: Response of the Combined Controllers

TABLE II. SUMMARY OF THE CHARACTERISTIC PERFORMANCE OF THE CONTROLLERS

	GA Tuned PI Controller	IMC Controller
Rise Time(sec) Tr	0.1	1.5
Settling Time(sec) Ts	3.8	4.5
Over Shoot (%)	4	0
Steady Error ess	0	0

Furthermore, an additional analysis and comparison of the controllers was done using the Integral of the absolute error (IAE). This technique is often used for the detection of performance degradation depending on the desired output. Table III shows the IAE results obtained from the open loop to the use of the GA-Tuned PI- controller and that of the IMC. From these results it can be deduced that the GA-Tuned PI controller has a significantly high performance as compared to the IMC controller owing to its low IAE value as show in Table II. This is however due to intelligent and stochastic nature of the GA in determining the controller parameters through series of iteration.

TABLE III. PARAMTERS VALUES

System	Value
Open loop	22770
GA Tuned PI Controller	1.914
IMC Controller	15

5. CONCLUSION AND FUTURE WORK

This paper has successfully evaluated the performance of an automated mobile liquid feed dispensing system using GA-tuned PI controller and Internal Model Controller (IMC).The performance of the dispensing system and the controller was evaluated using transient responses and Integral Average Error (IAE) metric respectively. The results obtained from the application of the GA tuned PI tuned controller to the system shows an improvement in terms of the transient response and also in terms of IAE controller evaluation. However, the system suffers a slight overshoot of about 4%. The application of IMC controller showed an improvement in terms of the zero overshoot and a slightly high IAE as compared to the GA tuned PI controller. The developed mobile liquid feed dispensing system has tendency to help farmer to solve the problems of poultry farmers by reducing the need for physical human involvement while administering poultry liquid feed to the poultry birds. They can feed a large number of poultry birds with contamination-free liquid feeds easily. They can also get increase in farm yield and maximize profit.

Some of the further researches that can be done are as follows:
1. The use of other intelligent techniques like PSO to tune the PID controller for the same mobile intelligent system.
2. Further performance evaluation of PSO to tune PID with capability to dispense both liquid and solid feed.
3. Adding sensors like level sensors, pressure sensors, light sensors and light sensors can also be added to the design.

REFERENCES

1. Adedisewo, O. (2004). Design and Construction of a Computer Controlled Poultry Feed Dispenser and Temperature Regulator. *Bachelor of Technology. Thesis, Department of Computer Science and Engineering, Ladoke Akintola University of Technology, Ogbomosho, Nigeria.*

2. Adewumi, O.,O. (2014). Design and Development of an Intelligent Poultry Liquid Feed dispensing System. *Bachelor of Engineering Thesis. Department of Computer Engineering, Federal University Of Technology Minna, Niger state, Nigeria.*

3. Adewuyi, A. P. (2013). DC Motor Speed Control: A case between PID Controller and Fuzzy Logic Controller. *International Journal of Multidisciplinary and Sciences and Engineering, 4(4),*36-40

4. Arulogun, O. T., Olaniyi O.M., Oke, O.A., & Fenwa,D.O., (2010). Development of mobile Intelligent Poultry Feed and Water Dispensing System. *Medwell journals of Engineering and Applied Science, 5*(3), 229 - 233.

5. Costa, J.G .(2011).PID Controller. Retrieved online from http://www.powertransmission.com/issues/0411/pid.pdf (25th April, 2015)

6. Folorunso, T A, Ismail F S., Pump Scheduling optimization model for water supply system using AWGA. *Proceedings of 2013 IEEE Symposium on Computers & Informatics (ISCI 2013)* (pp. 11-16) Kuala Lumpur, Malaysia.

7. Folorunso, T. A, Bello S. H, Olaniyi O. M. & Norhaliza A.(2013). Control of a Two Layered Coupled Tank: Application of IMC, IMC-PI and Pole-Placement PI Controllers. *International Journal of Multidisciplinary Sciences And Engineering (IJMSE), 4(11),*1-6.

8. Gen, M, & Cheng, R. (2000), *Genetic Algorithms and Engineering Optimization.* John Wiley. New York

9. Olaniyi, O. M., Folorunso T. A., Akogbe A. M, Adejumo, A. (2015). Design of a Mobile Poultry Liquid Feed Dispensing System Using PID Control Technique. *Proceedings of International Multidisciplinary and Interdisciplinary Conference on Science ,Technology,Education, Arts,Management and the Social Sciences (ISTEAMS 2015),*University of Ilorin, Ilorin, (pp107-114):The Creative Research and Technology Education Networks.

10. Olaniyi, O. M, Salami, A. F., Ahmed, A. & Adewumi, O. O. (2013). Design of an Intelligent Poultry Water Dispensing System Using Fuzzy Logic Control Technique", ISTEAM Research Nexus 2013, *Proceedings of International Multidisciplinary and Interdisciplinary Conference on Science ,Technology,Education, Arts,Management and the Social Sciences* (ISTEAMS 2013),Vol. III, 153-164):The Creative Research and Technology Education Networks.

11. Olaniyi, O. M., Salami, A. F., Adewumi O. O., O.S Ajibola (2014). Design of an Intelligent Poultry Feed and Water Dispensing System Using Fuzzy Logic Control Technique", *Journal Of Control Theory and Informatics (JCTIS)* , 4, (9) , pp. 61- 72.

12. Rivera D.E.(1999) , "Internal Model Control, A Comprehensive View," *Arizona State University, Tempe, Arizona 85287-6006,* October 27, 1999

13. Rivera, D.E, Morari, M. & Skogestad, S. (1986). Internal model control: PID controller design. *Industrial & engineering chemistry process design and development, 25,* 252-265,

14. Srinivas, P., Vijaya, Lakshmi, K ., Naveen, Kumar, V. (2013). Design of GA based PID Controller for three tank system with various Performance Indices. *International Journal of Soft Computing and Engineering (IJSCE), 3*(5), 206 - 209.

15. Tandon, B &. Kaur, R (2011). Genetic Algorithm based Parameter tuning of PID controller for composition control system. *International Journal of Engineering Science and Technology (IJEST), 3*(8), 6705-6711.