

## A Mobile Intelligent Poultry Feed Dispensing System Using Particle Swarm Optimized PID Control Technique

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### ABSTRACT

Poultry farming in the tropics incurs a high cost on farmers due to the manual pattern of feeding. This in turn gives a low return on investment, low yield and low profit. These shortcomings of the manual pattern of feeding are as a result of contamination of the poultry feed, wastage of the feed, fatigue and stress involved with monitoring of the birds and administration of the feed. This study describes the development of a mobile intelligent poultry feed dispensing system using Particle Swarm Optimization (PSO) tuned Proportional Integral Derivative (PID) control technique. The system is capable of moving in a structured environment within a deep litter poultry farm and dispenses solid and liquid feed to poultry birds. The performance of the system was evaluated in terms of the system response using the Overshoot, Rise time and settling time as parameters. The result after successful testing and performance evaluation of the system showed that the system can be used by farmers to easily administer both solid and liquid feed to poultry birds with a high return on investment, high yield and profit. The developed mechatronic system can be adopted by farmers to reduce high level of human involvement in poultry feeding.

**Keywords:** PID controller, Particle Swarm Optimization, Microcontroller, Feed, Dispensing, Precision Farming

### 1. BACKGROUND TO THE STUDY

Poultry farming is still carried out manually in the tropics at an exorbitant cost with low return on investment despite the benefits of Precision Farming to livestock management. Poultry is the rearing of a group of birds such as domestic chickens, geese, turkeys and guinea fowls for the primary purpose of egg and meat production (Olaniyi, Salami, Adewumi and Ajibola, 2014). The poultry industry contributes greatly to the development of the Nigerian economy as it serves as a major source of egg and meat which have a high nutritional value in the supply of protein. There are mainly four management systems employed in the rearing of poultry birds which are the Free Range system, Battery Cage system, Deep Litter system and Perchery houses (Afolami, Aladejebi and Okojie, 2013).

Particle Swarm Optimization (PSO) is a global optimization method developed by Kennedy and Eberhart in 1995. PSO was developed from swarm intelligence and primarily based on the behaviour of bird flocks and fish schools. The PSO algorithm emulates the behaviour of animal groups that have no leaders and hence will find food by random (Bai, 2010; Rini, Shamsuddin and Yuhani, 2011). The particles search for food and communicate with one another. While they are searching for food, there is always one particle that has better resource information about where the food source can be located. Hence, through the communication, the particles will eventually converge towards the food source (Hussien, Selamat, Daud and Abidin, 2014). The process of the PSO algorithm to find optimal solutions to problems follows the behaviour of these particles (Rini *et al.*, 2011).

PSO has many advantages over other global optimization methods such as fast convergence, simplicity and the ability to drive nonlinear plants and high order systems (Jaafar, Mohamed, Jamian, Aras, Kassim and Sulaima, 2014). A number of related works exists in the application of precision farming technique to poultry feed dispensing system in literature. In Arulogun *et al.*, (2010) a mobile intelligent poultry feed dispensing system was developed. The system was able to move, detect and avoid obstructions and dispense solid feed to poultry birds. But some of the limitations of this system were that it could not dispense liquid feed and the solid feed was not only unhygienically dispensed, dispensed was too large for the chicks to feed on. In Olaniyi *et al.*, (2014), a mobile intelligent poultry feed and water dispensing system was designed using fuzzy logic control technique. The system is capable of sensing the feed and water level and dispenses feed and water when the levels were low.

But some of the limitations of this system were that it was not mobile and fuzzy logic is not suitable for highly complex systems as it requires a lot of data and expertise to develop fuzzy rules and membership functions (Godil, Shamim, Enam and Qidwai, 2011). In addition, Adewumi, (2014) designed and developed an intelligent poultry liquid feed dispensing system using fuzzy logic to address the limitations of Arulogun *et al.*, (2010). Although the system was able to detect the level of the feed and dispense the feed if the level was low, it had limitations such as the inability of dispensing solid feed, immobility and the absence of a mechanism to prevent contamination.

Adejumo, (2015) addressed some of the limitations of Adewumi, (2014) by developing a mobile intelligent poultry liquid feed dispensing system using GA tuned PID control technique. This system was mobile and dispensed the liquid feed in a recycling manner to avoid contamination. But the major limitation of this system was that it was not capable of dispensing solid feed. In addition the GA technique used suffers from premature convergence and is not efficient in solving large optimization problems (Jalilvand *et al*, 2011). In Umogbai, (2013), a mechanical family poultry feeder was developed. This system was capable of dispensing solid feed to the feeder trough from the hopper. The system controlled the amount of feed dispensed using a spring and depended on the weight of the feed in the trough. Some of the limitations of this system were that it was large in size, immobile and was not capable of dispensing liquid feed.

Furthermore, there have been related works in the area of PID controller tuning with PSO. In Hussein *et al.*, (2014), PSO was used to tune the PID controller for a coupled tank system. The study showed that the PSO tuned PID controller exhibited better performance than the PID controller that was tuned using classical techniques such as Zeigler-Nichols, Cohen-Coon and Trial by Error methods. Similarly, Thangavelusamy and Ponnusamy, (2014) carried out a study on the comparison of PI controller tuning using GA and PSO for a multivariable experimental four tank system. The system compared the performance of decentralized PI, GA tuned PI and PSO tuned PI controllers. The results showed that the PSO tuned PI controller showed better performance and robustness in both servo and regulatory responses.

In this paper, we address salient limitations in these related works such as immobility (Umogbai, 2013; Adewumi, 2014), contamination (Adewumi, 2014), inability to dispense liquid feed (Umogbai, 2013; Arulogun *et al*, 2010) and inability to dispense solid feed Adejumo, (2015). Our mobile and intelligent system is capable of addressing these baseline related works by developing a system that is capable of dispensing both solid and liquid feed simultaneously using an intelligent PID control technique tuned by PSO algorithm for optimal performance.

The remaining part of the paper is organized into seven sections. Section 1 presents a review of related works on poultry feed dispensing system while the problem statement which serves as a motivation for this study is stated in section 2. Section 3 states the objective of this study while the system design considerations for hardware, software and mechanical subsystems are presented in Section 4; Section 5 presents the developed system and its performance evaluation with and without controller. Section 6 concludes and presents gaps for future research endeavour in enhancing poultry feed dispensing systems while the major contribution to knowledge of this study is presented in Section 7.

## 2. STATEMENT OF PROBLEM

A major challenge encountered in poultry farming is the manual pattern of feeding which is predominant in the tropics. This manual system of feeding has a lot of negative effects such as wastage of the feed, disease outbreak, improper administration of the feed, fatigue and stress involved in the manual pattern of feeding (Olaniyi *et al*, 2014). In addition, the time required to feed the birds at regular intervals is not sufficient and the feed cannot be left in bulk as this will result in selective feeding by the birds or spoilage of some parts of the feed (Arulogun, Olaniyi, Oke and Fenwa, 2010). Hence, there is a need to employ an intelligent method of feeding that will tackle these problems. Although a number of automated feed dispensing systems exist, many of these systems suffer from long response times and instability hence reducing the performance of the system (Olaniyi, Folorunso, Dogo, Bima and Adejumo, 2015). Therefore there is a need to employ a control technique to ensure that the system achieves optimal stability.

## 3. OBJECTIVE

The major aim of this study is to develop a mobile intelligent solid and liquid feed dispensing system using Particle Swarm Optimization (PSO) tuned Proportional Integral Derivative (PID) control technique for deep litter poultry farming.

## 4. METHODOLOGY

This section describes the materials and methodology used in the design and development of the mobile intelligent poultry feed dispensing system. The methodology is described according to system overview, hardware design considerations, software design considerations and the final integration.

### 4.1 SYSTEM OVERVIEW

The mobile intelligent poultry feed dispensing system (shown in Figure 1) consists of various components which include DC motors, DC pumps, wheels, microcontroller and the power supply unit. The system is capable of moving within a poultry farm as well as dispenses both solid and liquid feed to poultry birds. The system is capable of moving forward for five seconds and stop. After the movement, the system dispenses both the solid and liquid feed from their respective troughs into the feeder and drinker. To mimic human poultry attendant, the system wait for a feeding time of one minute in order to enable the poultry birds feed from it. In the structured environment, the system continues forward movement within the poultry farm and the entire process is repeated continuously. The system also has a solid feed sensing unit which determines the level of the solid feed before it dispenses. This is done to reduce the wastage of the feed. Figure 1 shows the overview of the mobile intelligent poultry feed dispensing system and Figure 2 shows the block diagram of the system

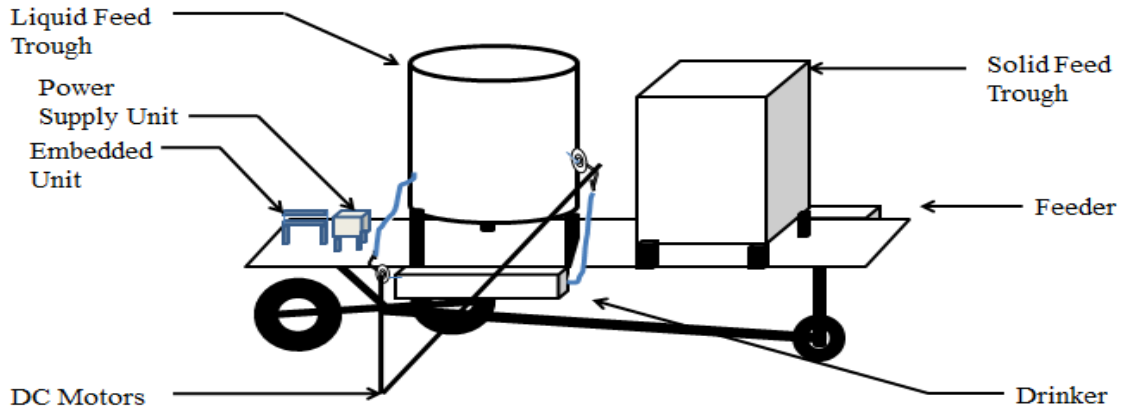


Figure 1: Overview of the mobile intelligent feed dispensing system

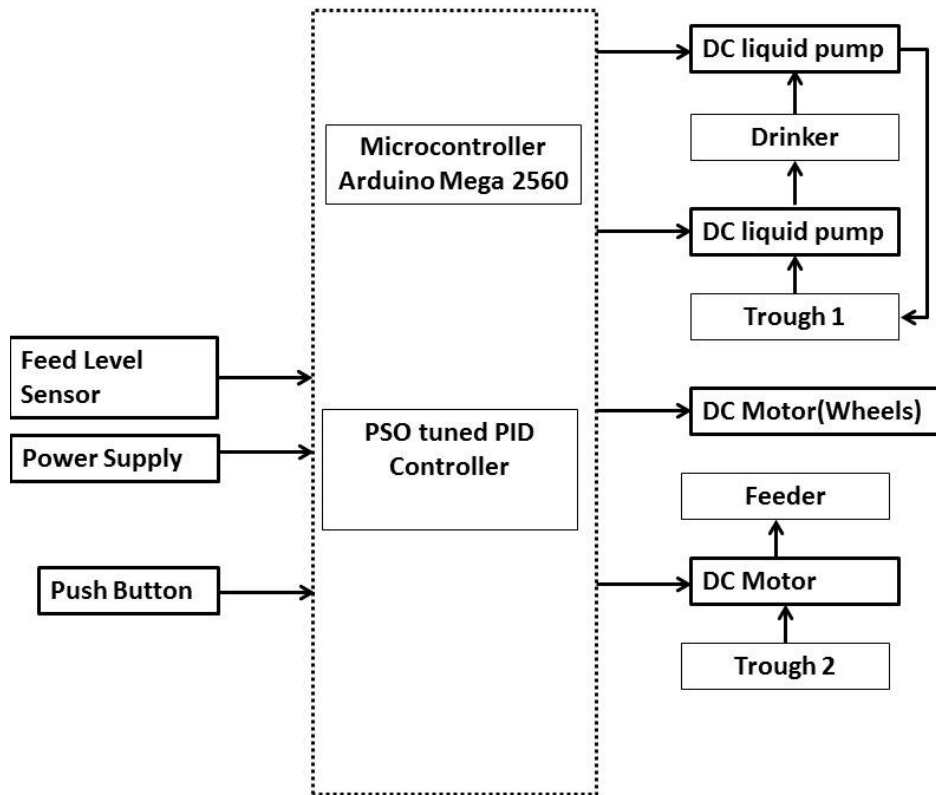


Figure 2: Block Diagram of the mobile intelligent poultry feed dispensing system

## 4.2 SYSTEM HARDWARE DESIGN CONSIDERATIONS

### 4.2.1 Electrical Unit

This mainly consists of the power supply unit. A 12V DC battery was used to power the mechanical unit, specifically the DC pumps and DC motors. The 12V generated by the DC battery was regulated to 9V using a 7809 voltage regulator to power the microcontroller. A relay circuit was connected between the microcontroller and the DC motors. This was accomplished to enable switching the voltage from the 5v supplied by the microcontroller to 12v needed to power the motors.

### 4.2.2 Embedded Unit

The mechanical unit, the solid and liquid feed dispensing units were controlled by Arduino Mega 2560 microcontroller which is characterized by its low cost, easier reprogramming and flexible libraries for the control of timers, interrupts and input/output devices (Elfasakhany, Yanez, Baylon and Salgado, 2011). This makes the microcontroller easy to acquire and also make it easy to control the input and output devices connected to the microcontroller board. In addition, the Arduino Mega 2560 microcontroller has many peculiar features which differentiate it from other microcontrollers. These features include: 256Kb Flash memory; 54 digital output pins; 16 analogue input pins; 16Mhz clock speed; 4Kb EEPROM; 8 Kb SRA; 4 UARTs; 16 MHz crystal Oscillator (Arduino, 2015).

### 4.2.3 PID Controller Unit

A closed loop control system technique was used in the design. Close loop systems provide feedback which is essential in achieving greater accuracy (Nise, 2011). A Proportional-Integral-Derivative close loop Controller was used as the control mechanism of the system. This is due to its ease of implementation in digital systems, robustness and cost maintenance (Jaen-Cuellar *et al*, 2013). The PID controller will be tuned using Particle Swarm Optimization (PSO) intelligent technique by using the PSO algorithm to generate the parameters for the PID controller.

Equation 1 shows the transfer function for a PID controller (Kambiz *et al*, 2012).

$$G_{PID}(S) = K_p + \frac{K_i}{S} + K_d S \quad (1)$$

### 4.2.4 Mechanical Unit

The mechanical unit consists mainly of the wheels and the DC motors. The DC motors have a rating of 12V and are responsible for the mobility of the feed dispensing system. A relay circuit is connected between the microcontroller and the DC motors. This is because the 5V supplied by the microcontroller is not sufficient to drive the DC motor. The driver thus steps up the voltage to 12V which is sufficient to power the motor. Only one wheel of the dispensing system was connected to a DC motor which in turn transfers motion to the other two wheels in Figure 1. The microcontroller sends a signal to the DC motor for it to move and when the motor starts rotating, the motion will be transferred to the other wheels.

### 4.2.5 Solid Feed Dispensing Unit

This unit was responsible for dispensing solid feed to the poultry birds. It comprises of the solid feed trough, a 12V DC motor connected to a conveyor and a feeder. The solid feed trough is expected to be filled with the appropriate solid feed to be administered to the birds. A feed sensing unit which comprises of a light dependent resistor checks the feed level and in turn determine if there is a need to dispense the feed or not. The microcontroller will then send a signal through the PID controller to the DC motor which will enable it to rotate. The rotation of the DC motor will in turn rotate the conveyor which will result in the dispensing of the solid feed to the feeder. The poultry birds feed from the feeder after feed is dispensed to the feeding for the pre-defined time determined by the microcontroller. A relay circuit is connected between the microcontroller and the DC motor so as to enable proper functionality of the system.

### 4.2.6 Liquid Feed Dispensing Unit

This unit of the system is responsible for dispensing liquid feed to the poultry birds. It consists of a liquid feed trough, two 12V DC liquid pumps and a drinker. The liquid feed trough will be filled with the liquid feed to be administered to the birds. The microcontroller sends a signal through the PID controller to the liquid feed pump which will in turn dispense the liquid feed to the drinker. After a while, the other liquid feed pump conveys the liquid feed in the drinker back to the trough in a recycling manner. This is done to reduce the rate of contamination of the liquid feed. A relay circuit is also connected between the microcontroller and the DC liquid pump to ensure proper functionality of the system. Figure 3 shows a circuit diagram interfacing all the units of the system.

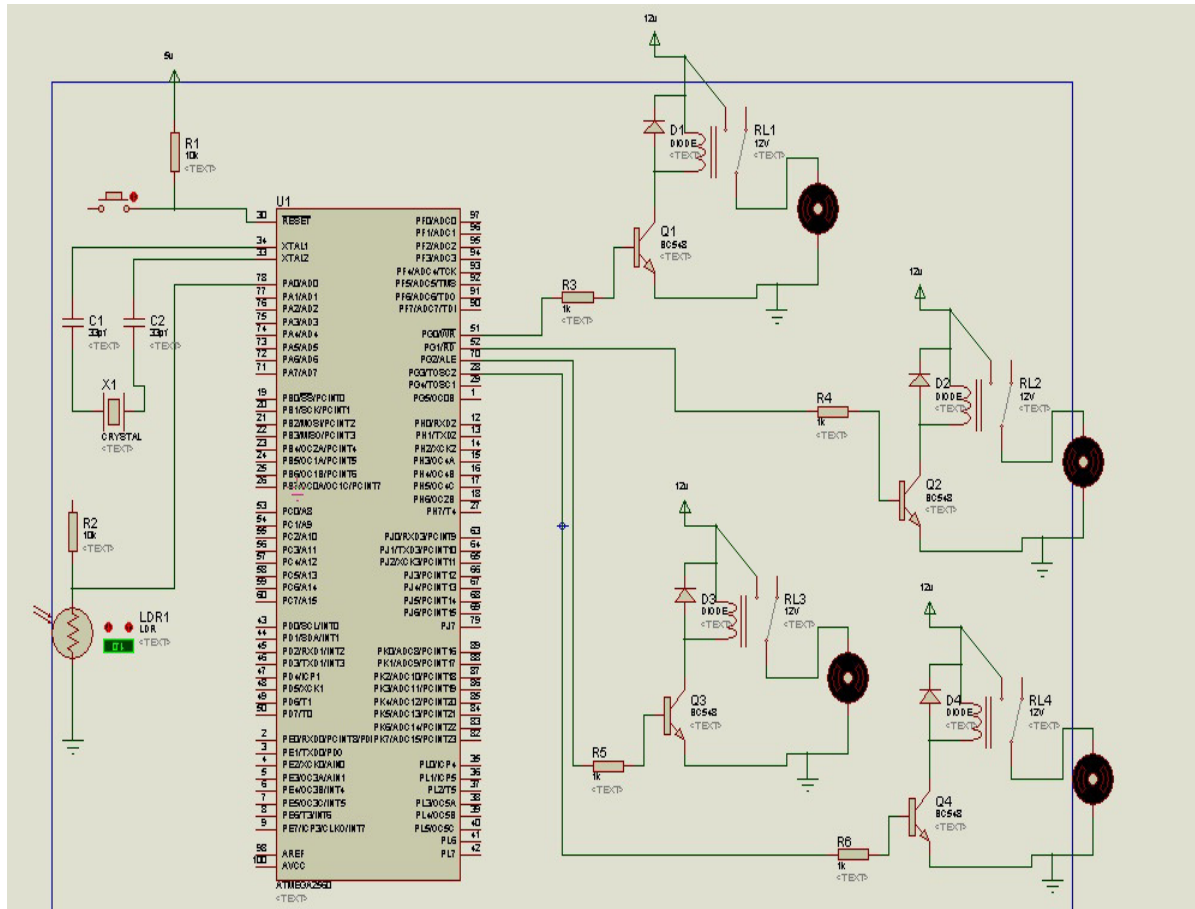


Figure 3: Circuit of the Mobile Intelligent Feed Dispensing System using PSO tuned PID control Technique (replace with one without grid)

#### 4.3 System Software Design Considerations

The PSO algorithm was implemented using MATLAB R2013a. The algorithm was used to generate parameters for the PID controller which are the proportional, integral and derivative gains. The PSO algorithm has various parameters which are used in the implementation of the algorithm.

These selected parameters were used by the algorithm to optimize the values of the proportional, integral and derivative gains of the controller. The following are the input parameters to the PSO algorithm:

- Swarm Size:** This refers to the total number of particles in the swarm. The swarm size chosen in this paper is 100 with 50 iterations (bird steps). This parameter was selected in order to provide a balance between the speed of evaluating the optimum value and also the efficiency of the algorithm.
- Acceleration Coefficients:** These are represented as C1 and C2. The sum of C1 and C2 give the convergence factor which determines how fast the PSO algorithm converges to the optimal solution. C1 and C2 have the values of 2.
- Inertia Weight:** This controls the influence the previous velocity has on the current velocity. The larger the inertia weight, the more the ability of the PSO algorithm to search in the global domain. The smaller the inertia weight, the more the ability of the algorithm to search in the partial domain. The inertia weight chosen in this paper is 0.9

The performance of the system was simulated and evaluated using MATLAB R2013a. The whole system was designed and simulated using Proteus software while the Arduino Mega 2560 microcontroller was programmed using the Arduino IDE. Figure 4 shows the flowchart of the overall intelligent dispensing system.

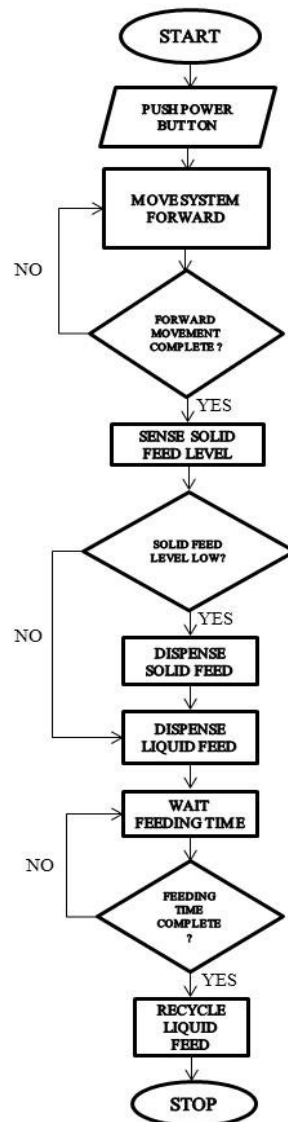


Figure 4: Mobile Intelligent Poultry Feed Dispensing System Flowchart

#### 4.4 SYSTEM MATHEMATICAL MODELLING

The system mathematical model was obtained based on the relationship between the input and output of the system. The solid and liquid feed dispensing units of the system were modelled separately. The solid feed dispensing unit of the system was modelled based on the DC motor while the liquid feed dispensing unit was modelled based on the rate at which the liquid flows out of the trough. The transfer functions obtained for both the solid and liquid feed dispensing units are shown in equations (2) and (3) respectively. Figure 5 shows the system model implemented in MATLAB. The model of the system was simulated after development of the system and the performance was evaluated in terms of system response.

$$G_l(s) = \frac{8.5}{s+0.07142} \quad (2)$$

$$G_s(s) = \frac{3.475}{0.003745s^2 + 0.515995s + 12.33831} \quad (3)$$



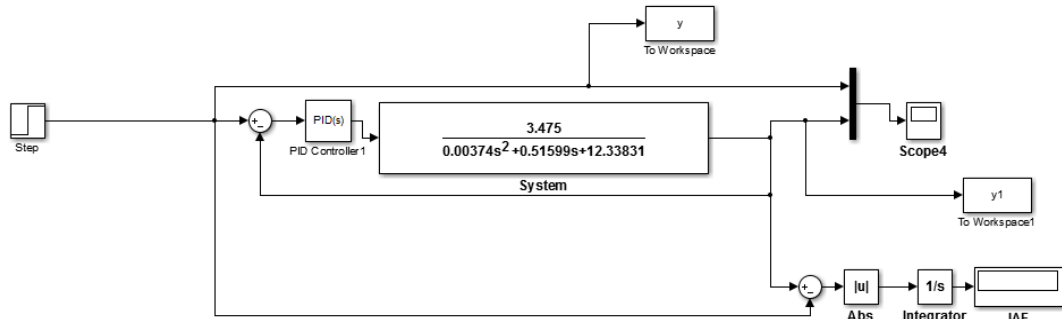


Figure 5: System Model Block Diagram in MATLAB

## 5. DISCUSSION OF FINDINGS

Figure 6 shows an overview of the developed prototype of the mobile intelligent poultry feed dispensing system. The system is capable of dispensing solid and liquid feed to poultry birds, as well as move within its structured environment with no human intervention.



Figure 6: Overview of the developed mobile intelligent poultry feed dispensing system

The performance of the system using the PSO tuned PID controller was evaluated in terms of the rise time, settling time and overshoot. Figure 8 and 9 show the system response of the liquid and solid feed dispensing units respectively.

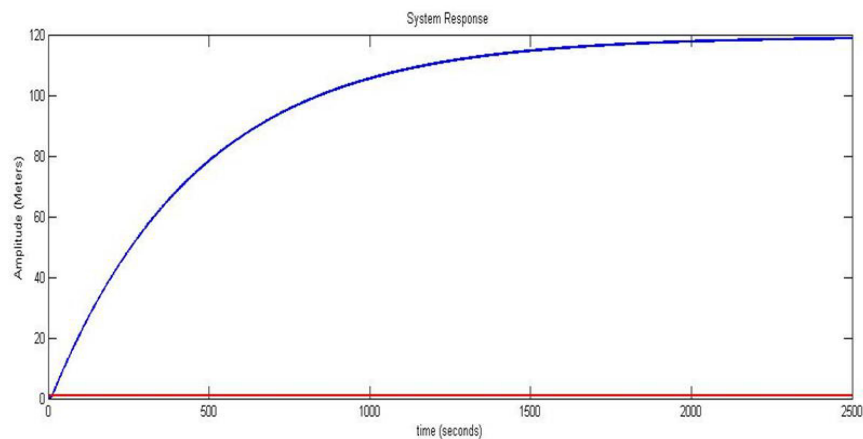
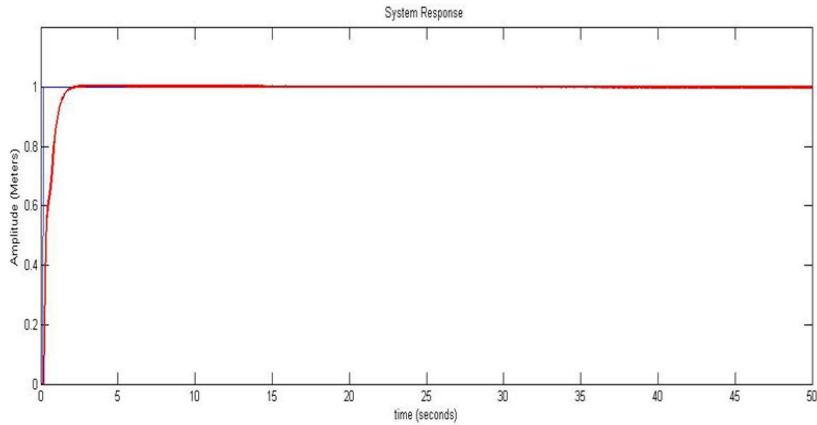
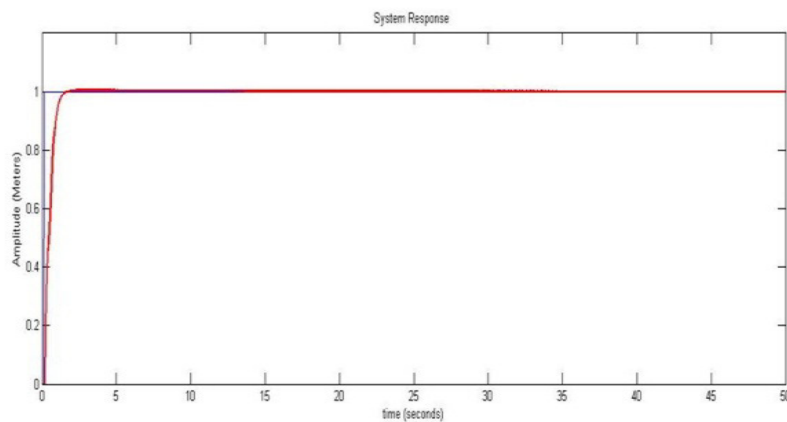


Figure 7: System Response without a PID controller



**Figure 8: System Response of Liquid Feed Unit**



**Figure 9: System Response of Solid Feed Unit**

From Figure 7, it can be seen that the system implemented without a PID controller has a very large overshoot and settling time. This shows that the system will take a very long time to achieve stability. The liquid and solid feed units of the system implemented with the PSO tuned PID controller showed better results than the system without the controller as shown in Figure 8 and 9 respectively. The PSO tuned PID controlled systems had lower settling times and low overshoot. This indicates that the system will achieve stability faster than the system implemented without the controller. Table 1 shows a summary of the performance of the system.

**Table 1: Summary of System Performance Evaluation**

Parameter / Stage	Without Controller	Solid Feed System (PSO)	Liquid Feed System (PSO)
$K_p$	-	1.5825	1.5825
$K_i$	-	0.2278	0.2278
$K_d$	-	0.0536	0.0536
Rise Time (seconds)	1.015	1.004	1.005
Settling Time (seconds)	Very Large (>100)	13.200	12.600
Overshoot (%)	Very Large (> 100)	0.498	0.498



## 6. CONCLUDING REMARKS & RECOMMENDATIONS FOR FUTURE RESEARCH AGENDA

The development of the mobile intelligent poultry feed dispensing system using PSO tuned PID control technique was achieved successfully. The system was developed in line with the design and the results obtained showed that the PSO tuned PID system showed better performance than the system without a controller. The application of the developed system in the poultry industry will immensely reduce the labour poultry farmers undergo in feeding their poultry birds. The system will also provide a cost effective method of administering feed to poultry birds, reducing contamination, reducing wastage and also provide a method that is easy to adopt by poultry farmers. This in turn will result in an increase in profit and yield.

Although the developed system addresses some limitations in previous works, the system can be improved in the following ways:

1. The use of hybrid intelligent techniques by combining two or more intelligent techniques such as GA-PSO and Fuzzy-GA in order to improve the system performance.
2. The incorporation of a power management system to control the use of power as well as make optimal and efficient energy consumption.
3. The system can be enhanced to operate in an unstructured environment.
4. Other controllers such as IMC and PI controllers can be used in implementing this system so as to evaluate the performance with different controllers and make recommendations based on the results obtained.

## 7. CONTRIBUTIONS TO KNOWLEDGE

This work has developed a prototype for a mobile intelligent poultry feed system for reducing high level of human involvement in deep litter poultry feeding. The results obtained proved that PSO tuned PID controller showed better system performance for reduction of feed wastage and better return of investment in poultry farming in deep litter scenario.

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