Chapter 21
Design of a Robot for the Welfare of the Poultry

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Abstract This paper is on the design of an automatic robot for the welfare of the poultry. The poultry farming is a growing segment of the agriculture in India. The poultry farming creates significant air pollution. To reduce the environmental impacts of the poultry farming, a waste management is considered as the effective method. The implementation of a waste management in the poultry farm incurs the physical contacts between the birds and the personnel and leads to the spread of different diseases. To resolve these problems, an automatic robot is designed. The robot continuously maneuvers on the floor. The underneath tool scrubs the floor and makes the litter and bird waste upside down. Therefore, the odor and the time required to dry the waste reduce. In addition, the bird movement and the production rate are increased.

21.1 Introduction

Poultry farming is a growing sector within the agriculture domain in our country. It is usually classified into organized and unorganized industrial sector. The requirements of organized and unorganized sectors are different. The organized sub-sector follows all the rules tested by various corporations throughout their productions. Poultry farming is principally divided into two kinds of business models, viz broiler production and egg production. More than 80% of boiler production output is produced in the organized sector [1]. The various methods are used in broiler production to keep birds in the poultry farming like intensive and unconfined poultry, layer poultry, organic, yarding methods, etc. Usually, intensive poultry farming is used for a larger variety of poultry birds with high stocking density [2]. According to the Worldwatch Institute, "Around 74% of total poultry meat and 68% of total poultry eggs area unit created from intensive poultry farming

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A. N. R. Reddy et al. (eds.), *Intelligent Manufacturing and Energy Sustainability*, Smart Innovation, Systems and Technologies 265,
https://doi.org/10.1007/978-981-16-6482-3_21

method" [2]. This method is economical considering factors such as land, feed, labor, and alternative resources and increases the production. In India, the poultry farming business is fully controlled by the farmer. It ensures continuous production throughout the year. However, some disadvantages of this method are generating health risks and environmental threats.

The characterization of wastes and their main elements such as ways of disposals, water quality impact, chemical and microbiological dynamics, etc. [3]. Characterization of wastes is principally because of three factors viz. poultry litter, poultry manure, and dead birds. Poultry litter refers to the material utilized by the poultry for bedding throughout the assembly cycle. The litter material is typically wood, packing, wheat straw, peanut hulls, or rice hulls. Generally, during the broiler production, the accumulating manure is mixed with the litter. The production of litter is influenced by age and breed of chickens, the density of confinement, feed conversion rate, feed volume, type and amount of litter, wet content of litter, floor surface, weather conditions during litter accumulation, and organic matter.

There is a huge amount of various gases trapped inside poultry litter and manure like carbon (C), ammonia (NH_3), nitrate (NO_3), chlorine (Cl), phosphorus (P), potassium (K), etc. The compositions of various gases in poultry litter and poultry manure are given in Tables 21.1 and 21.2.

The main reason of bad odor spread in the poultry and its surrounding is due to the trapped gases [4]. The magnitude of the environmental impact of poultry farming depends on production practices, particularly on manure management practices. The lack of awareness and the capital cost are two factors that affect the implementation of manure management practices [5–24].

The manure management practices are implemented through the collection of poultry litter (once a week in the dry season and twice in a week in the rainy season)

Table 21.1 Composition of gases in poultry litter (g in kg of litter) [3]

Gases	Reported mean	Range
Carbon (C)	376.0	277.0–414.0
Ammonia (NH_3)	4.6	0.10–20.10
Nitrate (NO_3)	0.20	0.0–0.70
Chlorine (Cl)	12.7	6.0–50.0
Phosphorus (P)	14.30	8.0–25.8
Potassium (K)	20.70	13.0–45.70

Table 21.2 Composition of gases in poultry manure (g in kg of manure) [3]

Gases	Reported mean	Range
Carbon (C)	290	223–327
Ammonia (NH_3)	14.40	0.210–29.90
Nitrate (NO_3)	0.40	0.03–1.50
Chlorine (Cl)	24.50	6.0–60.0
Phosphorus (P)	20.70	13.5–34.0
Potassium (K)	20.90	12.5–32.5

and stored in the bags or dumped in the separate compartment. The collection of poultry litter is difficult in intensive and free-range poultry farming methods because birds roam over entire shed area. Therefore, the poultry farmer tries to dry the mixture of poultry manure and poultry litter on the floor by frequent scrubbing and making the litter upside down manually with local tools. It leads to contact between poultry birds and human, and diseases may spread from human to the birds. In this paper, a design of robot is proposed to address the above problem. The objectives are to design a robot so as to free out trapped gases in poultry litter and manure and to increase movement of birds. The robot scrubs the floor and make the litter upside down for quick dry. In addition, it prevents human–birds contact.

21.2 Methodology

The concept generation is an important stage for designing a new product. As per the poultry farmers' requirement, there is a need of automatic device (or robot) which performs the routine work such as scrubbing the floor and make the litter upside down. To define the specification of robot, the information on the nature of the shed, the density of birds in a shed, the path of a robot, a general obstacle in the path of a robot, etc., are collected.

The shed is a place where the birds are kept. The dimensions of a shed are helpful to decide a path of the robot during its operation. In addition, the information on the roughness of a floor helps to decide the traction of the wheels of a robot. The extra care on the change of floor surface characteristics due to poultry litter is considered. Traction is an important factor in the selection of wheel and type of drive given to wheel. There are four major types of robot wheel available such as standard, caster ball, Mecanum, and Omni wheel. In this work, a 6-inch standard wheel was selected (see Fig. 21.1b).

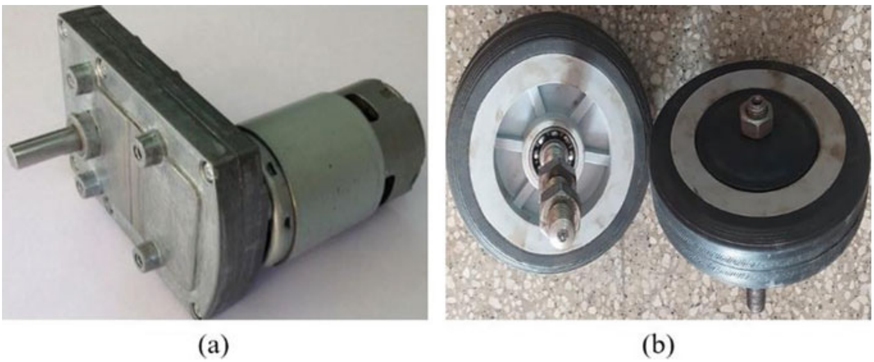

Fig. 21.1 Actual components **a** Motor. **b** Front wheels

The wheels are driven by means of a motor. The selection of motor speed and torque is obtained as follows,

$$\text{Rotational speed (RPM)} = \frac{\text{Robot, speed}}{\text{wheel circumference}}$$

$$\text{Torque} = \frac{\text{Mass of robot} \times \text{Accel. due to gravity} \times \text{Radius of wheel} \times \text{Coefficient of firction}}{\text{Number of wheel to be drive}}$$

In the above relation, the robot speed is fixed on the value of the maximum and minimum speed of the bird. The obtained motor speed and torque are 100 rpm and 5 Nm, respectively. However, the motor with 8Nm torque is selected considering safety factor and the market availability (see Fig. 21.1a).

A tool is designed to scrub the floor and to make the litter on the floor upside down. A shaft with curved blade arrangement is proposed as shown in Fig. 21.2. A shaft is driven by separate motor with sufficient torque to perform the task. The spacing between two blades and the geometry of curved blades is finalized based on initial prototypes.

To design an automatic robot, various electronic components such as microcontroller, distance sensor (ultrasonic sensor), servo motor, and motor controller are required. The microcontroller used in a present robot is Arduino UNO with ATmega328P microcontroller chip. It has 5 V operating voltage, 32 KB flash memory, and 14 digital pins out of which 6 pins provides pulse width modulation (PWM) output, 16 MHz frequency and 7 to 12 V input voltage, and 6 analog input pins (see Fig. 21.3a). Distance sensor is used to measure the distance of the robot from the wall of a shed. It is an ultrasonic sensor (HC-SR04 module) with

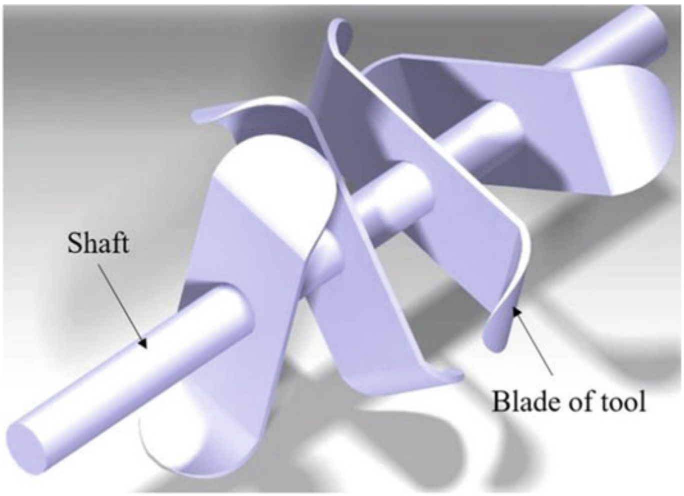

Fig. 21.2 CAD model of tool

specification, viz 5 V (DC) voltage, 15 mA operating current, and 40 Hz frequency. It measures distance in the range of 0.02–4 m (see Fig. 21.3b). The servo motor is used for rotating an ultrasonic sensor through 90° when the measured distance is less than the turning radius of a robot. It has a specification of 0.1765 Nm stall torque, 0.1 s/60° operating speed, 5 V operating voltage, and the mass 9 g (see Fig. 21.3c). The motor controller is used for connecting a microcontroller and the motor (see Fig. 21.3d).

A program in Arduino IDE software is written (see Fig. 21.4a). The above components are wired and interfaced with personal computer for testing. A detail flowchart is shown in Fig. 21.4b.

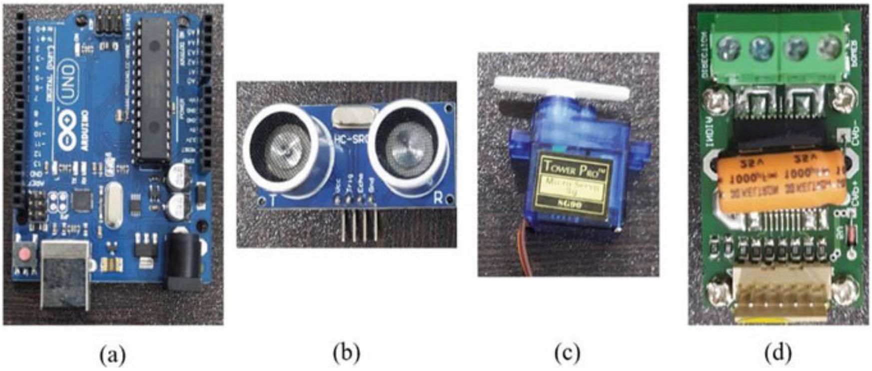

Fig. 21.3 Electronic components **a** Arduino UNO. **b** Ultrasonic sensor. **c** Servo motor. **d** Motor controller

Fig. 21.4 **a** A program in Arduino IDE software. **b** A detailed flowchart of a program

21.3 Result and Discussion

After following the methodology given in Sect. 21.2, an automatic robot is designed and developed. The dimensions of the robot are 400 × 350 × 200 (L × B × H) mm^3. A 3D CAD model of the automatic robot is developed in CATIA -V5 software. The rendered image of the robot is shown in Fig. 21.5.

The program in the microcontroller (Arduino UNO) allows the user to enter floor area. The robot automatically maneuvers on the floor area.

The robot moves in forward direction by means of DC motor and ultrasonic sensor continuously measures the distance of robot from boundary of poultry farm. When it reaches below the turning radius of robot, then it will stop at that point. Then, servo motor turns 90 degree in clockwise direction. Ultrasonic sensor above servo motor decides distance between wall and robot. If distance is above turning radius, then robot can take U-turn in clockwise direction and if not, it takes anti-clockwise U-turn. After completion of U-turn, it moves in forward direction. Robot repeats the above steps to cover the whole farm area.

The tool attached to the robot constantly rotates and scrubs the floor. It makes the litter on the floor upside down. Therefore, the trapped gases come out and reduces the dry time and the odor. According to the study, 6–7 days are required to dry a bird waste and the other litters on the floor. When the present automatic robot is used in the poultry, the time reduces to 2–3 days.

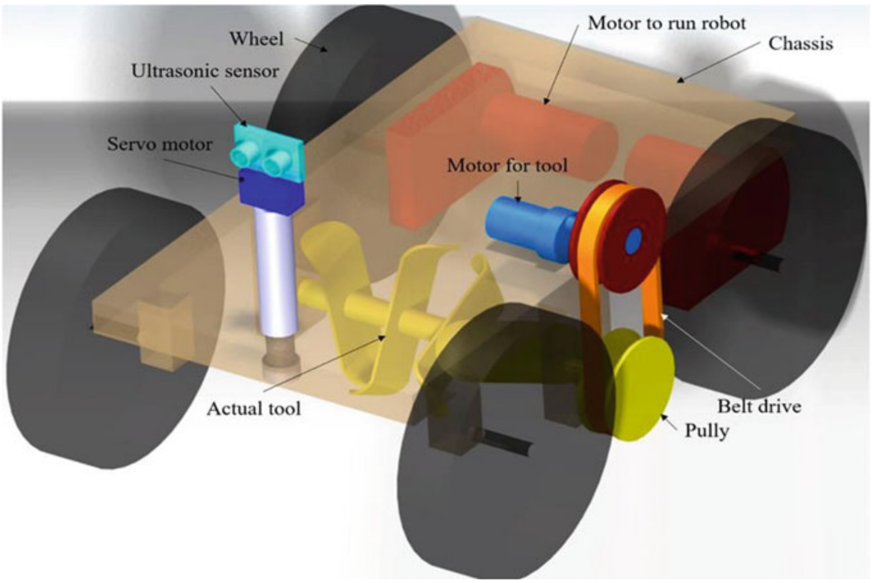

Fig. 21.5 Isometric view of automatic robot

According to the personal interaction with the local poultry farmers, nearly 45–50 days are required to grow the broiler birds from 300 g to 3 kgs in normal condition. When an automatic robot is used, the movement of the birds on the floor happens frequently. Therefore, the birds consume more grains and gain the required weight within 40–42 days. This helps a farmer to produce 2–3 more batches per year.

The main advantage of the automatic robot is that it reduces the human interaction with the birds and resulting diseases. Due to the removal of trapped gases from the bird waste and the other litters on the floor, the spread of the bird diseases is significantly reduced.

21.4 Conclusions

The poultry farming is a growing segment in the agriculture domain in India. The environmental impact due to poultry farming especially air pollution is high near to a poultry farm. The manual tool to make wastes upside down is a conventional method that can consume more time and leads to the spread of diseases from humans to poultry birds. To overcome these issues, an automatic robot is designed for the poultry farms. The automatic robot is found to be more effective in improving the air quality, the birds welfare, and production rate.

References

1. National action plan of poultry farming.: https://dahd.nic.in/sites/default/filess/Seeking-Commentson-National-Action-Plan-Poultry-2022 by 12–12–2017.pdf (2012)
2. Poultry Farming—Garden Pool.: https://gardenpool.org/facts/poultry-farming
3. Edwards, D.R., Daniel, T.C.: Environmental impacts of on-farm poultry waste disposal, biological and agricultural engineering department. Biores. Technol. **41**, 9–33 (1992)
4. Pelletier, N.: Environmental performance in the US broiler poultry sector: life cycle energy use and greenhouse gas, ozone depleting, acidifying and eutrophying emissions, science-direct. Agric. Syst. **98**, 67–73 (2008)
5. Maheshwar, S.: Environmental Impacts of Poultry Production. Poult Fish Wildlife Science (2013)
6. Rodić, V., Perić, L., Đukić-Stojčić, M., Vukelić, N.: The Environmental Impact of Poultry Production, Institute for Animal Husbandry, Belgrade-Zemun Biotechnology in Animal Husbandry, vol. 27(4), pp. 1673–1679 (2011)
7. Baxevanou, C., Fidaros, D., Bartzanas, T., Kittas, C.: Energy Consumption and Energy Saving Measures in Poultry. Energy Environ. Eng. **5**(2), 29–36 (2017)
8. Akers, J.B., Harrison, B.T., Mather, J.M.: Drying of poultry manure—an economic and feasibility study. In: Managing Livestock Wastes. Proc. 3rd Int. Symp. on Livestock Wastes. ASAE, St Joseph, MI, pp. 473–477 (1975)
9. Ammerman, C.B., Henry, P.R., Vijchulata, P.: Influence of cage layer manure on tissue mineral levels of finishing steers. In: Livestock Waste: A Renewable Resource. Proc. 4th Int. Symp. on Livestock Wastes. ASAE, St Joseph, M1, pp. 63–65 (1980)

10. Atkinson, G., Dietz, S., Neumayer, E.: Handbook of Sustainable Development. Edward Elgar, Cheltenham (2007)
11. Bolan, N.S., Szogi, A.A., Chuasavathi, T., Seshadri, B., Rothrock, M.J., Panneerselvam, P.: Uses and management of poultry litter. World's Poult. Sci. J. **66**, 673–698 (2010)
12. Akhtar, A.Z., Greger, M., Ferdowsian, H., Frank, E.: Health professionals' roles in animal agriculture, climate change, and human health. Am. J. Prev. Med. **36**(2), 182–187 (2009)
13. Are, K.S., Adelana, A.O., Fademi, I.O.O., Aina, O.A.: Improving physical properties of degraded soil: Potential of poultry manure and biochar. Agric. Nat. Resources **51**(6), 454–462 (2017)
14. DEFRA.: Consultation on 1.1.1 Sector Guidance Note IPPC SG8: Integrated Pollution Prevention and Control (IPPC), Secretary of State's Guidance for the A2 Rendering Sector. DEFRA Publications, UK (2008)
15. Arogo, J., Westerman, P.W., Heber, A.J., Robarge, W.P., Classen, J.J.: Ammonia in animal production—a review. Paper number 014089, 2001 presented at the ASAE Annual Meeting July 30–August 1, 2001, Sacramento, USA. American Society of Agricultural and Biological Engineers (2001)
16. Bowman, A., Mueller, K., Smith, M.: Increased animal waste production from concentrated animal feeding operations: potential implications for public and environmental health. Occasional Paper Series, No, 2. Omaha, USA, Nebraska Centre for Rural Health Research (2000)
17. Gvartyahu, G., Cunnigham, D.L., Van Tienhoven, A.: Filial imprinting, environmental enrichment, and music application. Effect on behaviour and performance of meat strain chicks. Poult. Sci. **68**(2), 211–217 (1989)
18. De Boer, I., Van Der Togt, P., Grossman, M., Kwakkel, R.: Nutrient flows for poultry production in the Netherlands. Poult. Sci. **79**, 172–179 (2000)
19. Delgado, C., Rosegrant, M., Steinfeld, H., Ehui, S., Courbois, C.: Livestock to 2020: The Next Food Revolution. International Food Policy Research Institute, Washington, DC (2020)
20. IEEP.: The environmental impacts of trade liberalization and potential flanking measures. Stage 1 of a Report to DEFRA. London, Institute for European Environmental Policy (2005)
21. Nachman, K.E., Graham, J.P., Price, L.B., Silbergeld, E.K.: Arsenic: a roadblock to potential animal waste management solutions. Environ. Health Perspect. **13**(9), 1123–1124 (2005)
22. University of Maryland.: Broiler production and the environment. College Park, MD, USA, College of Agriculture and Natural Resources, University of Maryland (available at http://ag.udel.edu/iseq/images/EB_368_Poultry_Regs_book_6%2027%2006.pdf) (2006)
23. Tao, J., Mancl, K.: Estimating manure production, storage size, and land application area. Fact Sheet Agriculture and Natural Resources AEX-715–08, The Ohio State University Extension (2008)
24. Singh, P., Mondal, T., Sharma, R., Mahalakshmi, N., Gupta, M.: Poultry waste management. Int. J. Curr. Microbiol. App. Sci. **7**(08), 701–712 (2018)