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Development of Automated Chick Counting Machine using Mechatronics

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Abstract – *An automated chick counting machine using mechatronics was developed that aimed to reduce counting errors, improve counting speed, and acknowledge chick welfare. The machine performance was evaluated in terms of theoretical capacity, actual capacity, machine efficiency, power consumption, accuracy, and precision at different linear belt speeds LBS1, LBS2, and LBS3 of 10.6 cm/s, 16.0 cm/s, and 21.3 cm/s, respectively. The automated chick counting machine has an overall dimension (length, width, and height) of 1350 mm, 465 mm, and 756 mm, respectively. It has a mainframe, loading platform, chick conveyor line, side guards, counting chamber, and slide unit as its components. The samples used were day-old broiler chicks. The machine performance was tested in a single-factor experiment in a completely randomized design (CRD) with three (3) replications for each linear belt speed (10.6, 16.0, and 21.3 cm/s). Results showed that the machine attained a theoretical capacity, actual capacity, machine efficiency, power consumption, accuracy, and precision of 1367 - 2475 chicks/h, 1159 - 2106 chicks/h, 84.94 - 85.35%, 0.51 - 0.81 W-h, 91.67 - 95%, and 0.95 - 0.98, respectively. One-way ANOVA showed significant differences on theoretical capacity, actual capacity, and power consumption at different linear belt speeds. The fabrication and machine cost was Php 26,551 and Php 44,079, respectively.*

Keywords – *Automated Chick Counting Machine, Chick, Chick Counting, Chick Handling, Poultry Industry*

INTRODUCTION

Poultry farming has become one of the most important aspects of agriculture. In recent years, poultry production has shown steady growth due to its short production cycle which can address issues on food security and cash flow (Rahman, 2012).

The value of broilers produced during 2018 was $31.7 billion, which is 5 percent higher than in 2017. This accounts for 9.04 billion broilers produced in 2018, 1 percent higher than in 2017. Where 56.8 billion pounds of the total amount of live-weight broilers produced in 2018 was 2 percent higher than in 2017 (US Department of Agriculture, 2019). In the Philippines, as of the second quarter of 2019, the total inventory of chicken was estimated at 191.70 million birds. The inventory of layer chicken was recorded at 40.24 million birds or 6.5 percent higher than the previous year's record of 37.77 million birds. Also, broiler chicken inventory grew by 6.2 percent, from 64.94 million birds in 2018 to 68.97 million in 2019. However, records of broiler chicken production showed that there was a drop by 2.1 percent, from 63.63 million birds in 2018 down to 62.29 million birds in 2019 (PSA, 2019). This concludes that there is a need for special treatment when it comes to handling and transport of newly hatched chicks as it plays an important role in broiler production (Meijerhof, 1997, Mitchell, 2009; EFSA, 2011; de Lange, 2012).

Nowadays, there is an increasing demand for the improvement of chick handling facilities to be able to cope up with the production. One of the processes related to chick processing involves the counting of chicks; When it comes to this specific operation, many small-scale to medium-scale broiler chicken industries perform the counting of chicks manually. However, man's ability to count varies from person to person as with the fatigue that the workers experience as they continuously count, which causes unexpected errors. It was also stated in the article published by Hatchery Breeder Tip (2004) that handling and counting of chicks with the use of the human hand is one of the main

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stress-imposing activities involved in the hatchery. Stress can directly affect the chicks but also have long term implications, and it can even be critical. So, to solve this issue, one of the possible solutions is by applying an automated chick counting machine using mechatronics which will lessen human handling. It has been explored that mechatronics, a term coined for the combination of mechanical, control, and electronic systems (Naidu, 1995) helped in the automation of most processes. Additionally, combining machine vision with it has improved the productivity and efficiency of agricultural machines (Billingsley & Bradbeer, 2008). More so, the application of machine vision is highly preferable, especially in non-contact measurement, because it provides high speed and precise results as compared to manual counting (Baygin et al., n.d.).

Current innovations in automated catching and handling systems have been commercialized in the market (Mitchell & Kettlewell, 2004). Chick counting machine is one of the solutions to reduce injury and distress for birds and less human handling (Lacy & Czarick, 1998; Knierim & Gocke, 2003). In the early use of chick counters there was concern regarding the line speed of conveyor belts that practically threw the chicks through the process with some hard landings. In particular, drops from one conveyor belt to another must be avoided as they tend to cause injuries and wing-flapping (Mauldin, 2004). As for the reasons mentioned above, there is indeed a need to develop a chick counting machine that reduce counting errors, improve counting speed, and acknowledges chick welfare.

The development of a chick counting machine using mechatronics was the main aim of this study. It was evaluated at different linear belt speed in terms of the performance of the machine such as theoretical capacity, actual capacity, power consumption, accuracy, and precision.

OBJECTIVES OF THE STUDY

This study aims to develop and test an automated chick-counting machine using mechatronics. Specifically, the parts and features of the machine will be described thoroughly. The machine performance in terms of theoretical capacity, actual capacity, machine efficiency, power consumption, accuracy, and precision were tested at three different belt speeds (10.6, 16.0, and 21.3 cm/s) which corresponded to a roller angular speed of 40 rpm, 60 rpm, and 80 rpm, respectively.

MATERIALS AND METHODS

This section presents the details of the components of the automated chick counting machine, hardware installation, camera and sensor programming, machine performance testing, and statistical analysis.

Chick counting machine components

The designed chick counting machine was constructed from stainless steel and has an overall length, width, and height of 1350 mm, 465 mm, and 756 mm, respectively. In order to perform its intended function, there were six components: the mainframe, which served as the support structure of the whole system; the loading platform, which would be the stand for loading of the chicks; the chick conveyor line, which was responsible for the transport of chicks; the side guards, which secured the chicks from falling off the edge of the conveyor; counting chamber, which houses the camera and the control system; and lastly, the slide unit where the chicks were directed to the box after counting (Figure 1).

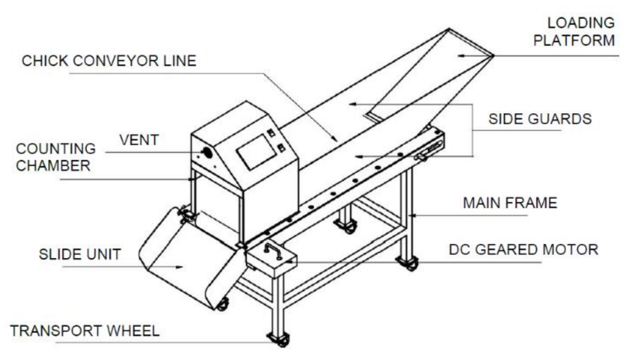

Figure 1. Components of the automated chick counting machine.

Hardware installation

The control system was enclosed inside the counting chamber located at the output end of the chick counting machine. The control system was composed mainly of the following: Pixy2 CMUCam5 camera, DC geared motor, VNH2SP30 DC motor driver, MicroSD card module, and Nextion TFT LCD. The image captured by the Pixy2 CMUCam5 camera, along with its information was sent to the Arduino Mega 2560 board which then displays the number of counted chicks on the Nextion TFT LCD. The control system was powered with a 12 VDC power supply. Moreover, a DC jack was plugged into the Arduino Mega 2560 and wired to the power supply. In contrast, the other components were lined to the microcontroller unit's voltage pins by applying solder between their

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connections. Figure 2 shows the connection of the electronic components involved and the direction of their communication.

The microcontroller unit used in the circuit was an Arduino Mega 2560. It has 54 digital input/output pins of which 15 can be used as PWM outputs, 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. For the chick counting, the Pixy2 CMUCam5 camera was used. It was first calibrated using the Pixymon software to assign an object to be detected by the camera.

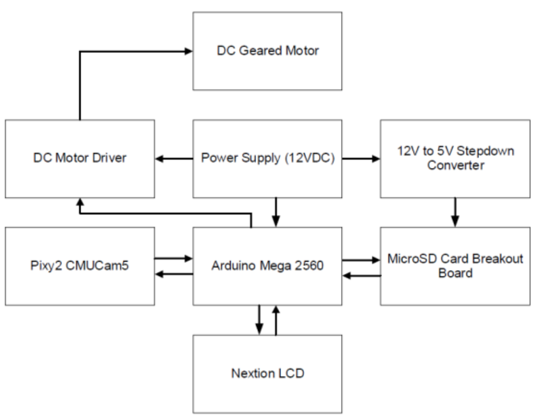

Figure 2. Diagram of electronic components.

Every machine vision system requires different lighting techniques to capture and process a workable image. After the preliminary installation of all the electronic components, the Pixy2 CMUCam5 camera module was tested and was observed to capture an image that was overexposed due to the direct lighting of the camera's built-in LED light (Figure 3). Hence, the sides of the counting chamber were painted with white color to diffuse the light. This paved for better illumination inside the chamber as well as enhanced the detection of the conveyed day-old chicks.

Figure 3. Walls of the counting chamber.

A 12-V DC geared motor was used to drive the chick conveyor line. It is connected to a VNH2SP30 motor driver which aided in controlling the revolution of the drive shaft of the conveyor. To regulate the speed, the motor driver was connected to a Pulse-Width Modulated (PWM) pin to receive PWM signals from the Arduino Mega 2560. Speed adjustment was applied on the Nextion touchscreen LCD by using two buttons which were labeled "+" and "-" and had an object name of plus and minus, respectively. Additionally, a progress bar was used to represent the range of the speed in terms of percentage (0% – 100%). Moreover, the actual linear belt speed was obtained by verifying the roller speed with a digital tachometer.

Camera and sensor programming

The process involved in calibrating the camera was a one-day-old chick, a personal computer (PC), and a micro USB cable (for serial communication between the camera and computer). Before testing, the camera was prepared and calibrated through color signatures in the software's Action menu tab (Figure 4). Initially, the chick was placed in front of the camera's lens. The first step was followed by viewing the video displayed on the main window of PixyMon. Assigning signature to the chick sample was performed by clicking the Action tab and "Assign signature 1". Afterwards, the captured image of the chick was outlined and evaluated the detection. Once the sampling was satisfactory the calibration was done. Consequently, it was further tested while the machine was running at full speed.

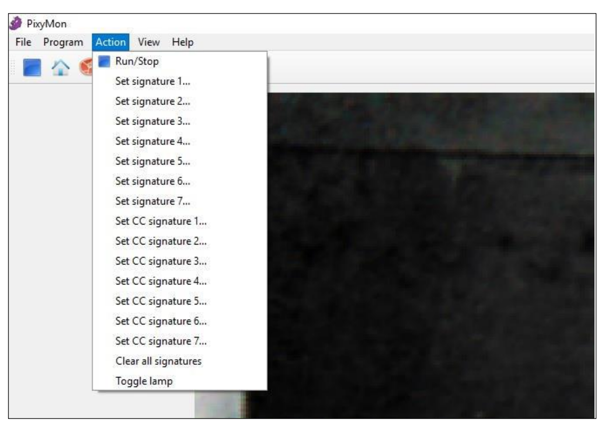

Figure 4. Assignment of the signature on the Action menu bar.

The camera processes the captured images and utilized the Color-Connected Components (CCC)

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algorithm. The utilized camera has a built-in vision processor integrated circuit (IC) which handles the execution of the image processing even without a personal computer (PC) connected to the whole system. Moreover, there is an external library that supports the communication of the Pixy2 CMUCam5 camera to the Arduino Mega 2560. By including the library in the main program, the parameters of the objects (chicks) detected by the image sensor were retrieved by using the following code: pixy.ccc.blocks[i].m.age returns the number of frames the chick was detected, pixy.ccc.blocks[i].m.height and pixy.ccc.blocks[i].m.width returns the area of the chick detected. Moreover, false detections were prevented from being counted by applying area limiting algorithm to the program (Figure 5).

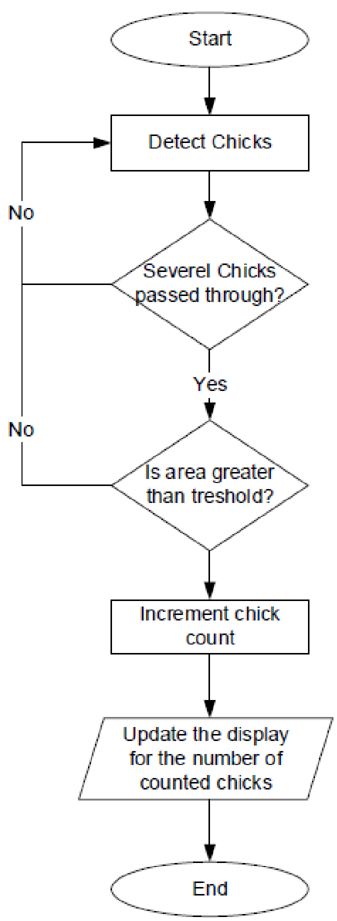

Figure 5. Flowchart of the program of chick counting.

Testing of machine performance

Before the actual testing, the machine was subjected to a series of pre-testing and calibration procedures to identify whether the machine had met the required function. The performance of the chick counting machine was tested at different linear belt speed of 10.6 cm/s, 16.0 cm/s, and 21.3 cm/s.

Statistical Analysis

The chick counting machine was tested in a laboratory setting. To obtain the data required for the machine performance test, a simple random sampling was applied in selecting the number of chicks to be counted. A total of 20 randomly selected one-day-old chicks for each linear belt speed were bought from a local poultry feed supplier located in Brgy. Mendiola, Siniloan, Laguna. To obtain a consistent result during the conduct of the test, only one-day-old chicks were used. Three linear belt speeds were tested with three replications in a Completely Randomized Design (CRD). Statistical indices such as mean, standard deviation, and variance were gathered.

The significant effect of the different linear belt speed settings on the machine performance of the automated chick counting machine was analyzed using One-way Analysis of Variance (ANOVA) at 5% level of significance followed by Duncan's Multiple Range Test (DMRT) (Gomez et al., 1984). The data were analyzed using SAS software.

RESULTS AND DISCUSSION

Machine Description and Features

The chick counting machine was developed to count one-day-old chick and display on a touchscreen liquid crystal display. The fabricated machine consisted of the components: the mainframe, loading platform; chick conveyor line; counting chamber; side guards, and the slide unit. In addition, the machine was designed with a portability feature by attaching caster wheels on the legs for ease of transport. Moreover, the weight of the machine was also considered by using lighter materials that have a greater contribution to its portability. It has an overall dimension (length, width, and height) of 1350 mm, 465 mm, and 756 mm.

Mechatronics was the main driving element of the machine. Specifically, the mechatronic part of the machine consisted of a DC-geared motor controlled by a VNH2SP30 motor driver that actuated the chick conveyor line when a digital signal was detected from the Arduino Mega 2560. It was toggled through the use of the touchscreen liquid crystal display provided on the display panel of the counting chamber (Figure 6). In addition, the Pixy2 CMUCam5 camera acts as an electronic vision. It has a capture rate of 60 frames per second (fps), which enabled the fast detection of chicks passing in its field of view.

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Figure 6. User interface of the machine's display.

Machine performance at different linear belt speeds

This section provides the summary of the data gathered along with the data analyzed based on the statistical analysis applied. To enhance the readability of the several parts of this section, the linear belt speed was shortened to LBS. Specifically, LBS1, LBS2, and LBS3 were

Table 1 shows the machine performance in terms of theoretical capacity, actual capacity, and machine efficiency. Moreover, table 2 contains the summary of machine performance in terms of accuracy, precision, and power consumption.

Table 1. Machine performance in terms of theoretical capacity and actual capacity.

Linear Belt Speed (LBS), cm/s	Theoretical capacity, chicks/h	Actual capacity, chicks/h
LBS1 – 10.6	1367[b]	1159[b]
LBS2 – 16.0	2242[a]	1842[a]
LBS3 – 21.3	2475[a]	2106[a]
Cv (%)	14.57	10.55
p-value	<0.01	<0.01

Significant means with ANOVA at 5% level of significance. Means with common letter are not significantly different with Duncan's Multiple Range Test (DMRT).

Theoretical capacity

The theoretical capacity attained was 1367 chicks/h, 2242 chicks/h, and 2475 chicks/h for LBS1, LBS2, and LBS3, respectively. In Table 1, it can be seen that as the linear belt speed increases, the theoretical capacity also increases. The increasing trend in the theoretical capacity at rising belt speed was attributed to the number of chicks that entered the counting chamber at a time. At higher speeds, the belt will travel more distance than the lesser speed giving ample time for the chicks to be in a position on the input end of the belt and to be transported to the counting chamber readily.

Actual capacity

Results showed that the actual capacity increases as the linear belt speed progresses. Moreover, the actual capacity attained ranged from 1159 chicks/h to 2106 chicks/h. The actual capacity yielded in LBS1 was affected by the belt speed. The cause can be linked to the chicks walking back to the input end of the chick conveyor line which expended longer counting time. In comparing the machine performance with manual operation, chicks can be counted accurately by a skilled farm laborer. A skilled farm laborer can count on an average of 1,080 chicks/h. During the operation, the actual capacity of the automated chick counting machine was comparable to the manual labor's average output.

Table 2. Machine performance in terms of machine efficiency and accuracy.

Linear Belt Speed (LBS), cm/s	Machine efficiency, %	Accuracy, %
LBS1 – 10.6	84.94[a]	93.33[a]
LBS2 – 16.0	83.66[a]	95.00[a]
LBS3 – 21.3	85.35[a]	91.67[a]
Cv (%)	12.27	2.53
p-value	0.98	0.30

Significant means with ANOVA at 5% level of significance. Means with common letter are not significantly different with Duncan's Multiple Range Test (DMRT).

Machine efficiency

The efficiency of the machine represents the percent of work performed to finish a counting operation. The highest observed machine efficiency was at LBS3 with a value of 85.35% and lowest at LBS2 with a value of 83.66%.

The results were comparable to the study conducted by Bala et al. (2019), wherein their corn sorting machine attained a sorting machine efficiency ranging from 82.76%-88.45%.

Accuracy

Results showed that LBS2 had the highest accuracy at 95% while the lowest was LBS3 at 91.67%. As observed during performance testing,

According to Adjanohoun et al. (n.d.), counting errors of less than 0.5% or greater than 95% were the typical accuracy obtained by commercial automated chick counting machines. The decrease in accuracy attained was affected by the number of samples used in the performance testing.

Table 3. Machine performance in terms of precision and power consumption.

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Linear Belt Speed (LBS), cm/s	Precision	Power consumption, W-h
LBS1 – 10.6	0.98[a]	0.81[a]
LBS2 – 16.0	0.95[a]	0.54[b]
LBS3 – 21.3	0.98[a]	0.51[b]
Cv (%)	1.43	12.04
p-value	0.14	<0.01

Significant means with ANOVA at 5% level of significance. Means with common letter are not significantly different with Duncan's Multiple Range Test (DMRT).

Precision

Results showed that the precision of the chick counting machine was consistent in terms of repeated testing. The highest precision was observed both at LBS1 and LBS3 at 0.98 while the lowest precision was LBS2 at 0.95.

As stated by Jones et al. (n.d.), a value is said to be precise when the acquired data is near the value of 1. Hence, the chick counting machine can output repeated accurate counts of chicks.

Power consumption

Results from Table 2 showed a decreasing trend in power consumption as the linear belt speed increased. The highest power consumption observed was on LBS1 at 0.81 W-hr followed by LBS2 at 0.54 W-h, and lowest on LBS3 at 0.51 W-h.

The rise in the power consumption of LSB1 is due to the longer time required to finish counting the chick samples. Since this setting is the slowest, it took considerable time to finish a counting operation. Moreover, the elongation in the operating time is caused by the chicks that were able to return to the input part of the chick conveyor line as compared to other belt speeds where the chicks are continuously carried and transported toward the counting chamber.

Cost of fabrication

The total cost of materials used in fabricating the Automated Chick Counting Machine was Php 16594.00 excluding the materials to be counted which are the chicks and the electronics. To simplify the analysis, the labor cost was assumed to be 60% of the total material cost and was determined to be Php 9957.00. The Php 5000.00 was allotted for the programming fee. Accordingly, the total cost of fabrication of the Automated Chick Counting Machine was Php 44079.00.

CONCLUSION AND RECOMMENDATION

Mechatronics was incorporated in the development of automated chick counting machine to be used for counting of chicks in local poultry farms. Specifically, the developed automated chick counting machine consisted of several parts mounted on the main frame such as the loading platform, chick conveyor line, counting chamber, and slide unit.

The developed machine was subjected to a test of its performance in terms of theoretical capacity, actual capacity, machine efficiency, accuracy, precision, and power consumption. Consequently, both data collected in theoretical capacity and actual capacity has an increasing trend as the linear belt speed increases as well. However, as speed increases, the machine efficiency stays the same at each setting. In terms of its accuracy and precision, the machine was able to provide a consistent accurate value. Based on the result, it was concluded that all linear belt speed settings can be used for chick counting operations. However, at LBS1, some chicks were able to counteract the forward travel of the belt which resulted in longer operating time.

Due to the global pandemic that affected many countries, including the Philippines, the conduct of the study was limited in several ways. Hence, discontinuities were experienced during the Enhanced-Community Quarantine. Thus, to fully characterize the performance and economic feasibility of the developed automated chick counting machine, further research, modification, and testing should be considered. Initially, some alterations can be made in the design of the loading platform as the chicks don't slide freely down to the chick conveyor line. By setting the loading platform into an adjustable one, the operator can take control of the inclination of the part. Also, the use of a smooth polyvinyl chloride (PVC) belt is suggested to prevent the chicks from staying at the output end of the chick conveyor line causing the number of chicks counted by the machine to be greater than the total number of chicks loaded onto the machine. Modifying the design of the counting chamber was also recommended as the machine lighting system was affected by light from the outside. Moreover, the machine should be subjected to further testing with a greater number of samples to be used.

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