Livestock Farming System for Continuous Estimation of Poultry Flocks Weights

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ABSTRACT

This project aims to develop a precision livestock farming system for continuous estimation of poultry flocks weights and install it on a poultry farm. A poultry scale was built, connected to an M2M gateway that processes the weights locally and streams the broiler's body weights to an online IoT cloud platform. To deal with the random fluctuations due to the unpredictability of bird behavior, an algorithm was created to generate valid body weights, and implemented in the gateway and C Sharp for testing purposes. The results obtained are proper evidence that the traditional way of poultry weighing can be replaced by an automated embedded system with higher accuracy which gives the farmers the ability to have real-time monitoring, from any location, reducing time spent, human resources, costs, and improving productivity and quality in poultry farms.

Keywords
Precision Livestock Farming, Automatic Poultry Weighing, Poultry Scale, Smart Farming

1. INTRODUCTION

The present work arose from a request from the breeders to develop a system that will allow them to monitor the growth of birds throughout the production cycle and specifically at the time of birds exit. Knowledge of birds weight has a significant impact on production, and is one of the most challenging and essential information about the flocks, for the reason that they are directly related to the bird's health and indirectly to the farm's sustainability. This study was done in a real poultry production environment, and it was necessary to address beyond the technical issues (equipment, hardware, communications, and software), market-related questions, human factors, and animal behavior. It also aims to confirm automatically-collected weights reliability, better understand the bird’s behavior during weighing, and the difficulties and reasons for their slow adoption by poultry breeders.

1.1 PROBLEM IDENTIFICATION

The United Nations recently released population projections based on data until 2012 and a Bayesian probabilistic methodology. Analysis of these data reveals that, contrary to previous literature, the world population is unlikely to stop growing this century. There is an 80% probability that the world population, 7.7 billion in 2019, will increase to between 9.6 and 12.3 billion in 2100 [1]. Aggregate meat consumption increased by almost 60% between 1990 and 2009, from 175,665 thousand tonnes to 278,863 thousand tonnes, driven in part by a growing world population [2]. Meat consumption has increased and is likely to continue. Growth is driven mainly by white meats, with poultry importance increasing globally. Consumers in developed countries are becoming more interested in meat production systems, animal welfare, food safety, and other quality-related matters [3]. The
production of meat consumes a considerable amount of resources, both directly and indirectly through the
cultivation of feed, and has several negative impacts on the environment [4], the magnitude of environmental
impacts is highly dependent on production practices and especially on manure management practices [5]. Climate
change is probably the most critical environmental issue of our time. Raising animals for food contributes to the
production of greenhouse gases implicated in global warming that is causing climate change [6].

2. LITERATURE REVIEW

2.1 PRECISION LIVESTOCK FARMING

PLF is a potential strategy to mitigate the problem since the primary goal of PLF is to make livestock farming
more economically, socially, and environmentally sustainable, through the observation, interpretation of
behaviors, and control of animals. Furthermore, adopting PLF to support management strategies may lead to the
reduction of the environmental impact of the farms [7]. It is defined as the application of process engineering
principles and techniques to livestock farming to automatically monitor, model, and manage animal production.
These envisaged real-time monitoring and control systems could dramatically improve the production
efficiency of livestock enterprises [8].

2.2 EARLY STUDIES ON AUTOMATED POULTRY SCALES

Early studies on the automatic weighing of chickens and their accuracy relate to the early years of the rise of PCs.
In 1984 were made trials in crops of broiler chickens with results indicate that the average body weight can be
estimated to within about ±2.5% [9]. The body weights obtained automatically were similar to body weights
recorded manually (P > 0.05) [10].

2.3 EXISTING POULTRY SCALES

Given that, poultry houses floors are uneven and dirty by broiler litter, becoming highly corrosive, nowadays, the
vast majority of the automatic chicken weighing scales on the market, are ceiling-mounted hanging scales equipped
with a display for local viewing of information. There are also some floor scales solutions on the market, but they
are in the minority. Furthermore, most of the scales work only as dataloggers, eventually with connectivity to a
PC or restricted to the vendor's platform.

2.4 BROILER CONTROLLED GROWTH FEED MODEL-BASED ALGORITHM

The control of the growth trajectory of broiler chickens during the production process based on an adaptive
compact dynamic process model, found that it should be possible to control broiler growth trajectories with
less feed intake [11].

3. PROPOSED APPROACH

The challenge was to create an automatic weighing system, integrate it into a PLF system, using the edge
computing paradigm, to build a reliable broilers scale, install it on a poultry farm, filter and process weights at a
legacy gateway, connect it to an IoT / PLF platform for remote weights storage, analysis, and display of collected
weights.
For this it was necessary to create an algorithm to solve the following issues with getting correct weights: variable litter on the scale, chickens stirring on the scale plate, multiple climbs and descents simultaneously, chicken bites and pushes on the scale, and make enough weighings to get statistical significance, and also develop software for algorithm implementation, weight analysis and validation.

An original lightweight algorithm that, without sacrificing its functionality, allows its implementation within the memory and processing limitations of the existing gateway, was created.

![Figure 1 - System Architecture using Edge computing-based IoT](image)

![Figure 2 - Weighing algorithm flowchart](image)
4. SYSTEM IMPLEMENTATION

4.1 WEIGHING DEVICE DEVELOPMENT

A scale was built from scratch, and the needed software to estimate the bird's body weights were developed.

![Figure 3 - Scale prototype.](image)

Scale size and weight have been dimensioned to allow the birds to climb up and down while ensuring their stability with the adjustable feet to be adapted to the growth of birds and uneven floors.

4.2 HARDWARE

To collect weight data, process, and communicate with the cloud, a legacy programmable M2M gateway equipped with a GPRS modem and a data SIM card was used, and a standalone enclosure has been assembled to not interfere with existing installations.

![Figure 4 - Farmcontrol Smartbox Mini](image)

4.3 SOFTWARE DEVELOPMENT

Different types of software have been developed, from PLC drivers, middleware, and data analysis applications on Microsoft Windows, to a WebSocket server in the cloud. For the middleware and data analysis, C Sharp was the chosen development language considering that it is one of the available by the gateway manufacturer SDK API to connect the Gateway to Windows Visual Studio IDE. The WebSocket server was developed in PHP and client-side in JavaScript, HTML, and CSS and the working database was Oracle MySQL.

4.4 DRIVER DEVELOPMENT FOR BIRDS WEIGHING

It was a challenge to develop the driver as described in the weighing algorithm, shown in Figure 2, for the used gateway, which has no floating arithmetic. The driver code is executed every second to read the input connected to the scale, and process the weighings, sending to the cloud a BW only when an individual chicken weight is detected. All development was done in a vendor-provided visual environment, using the different abstraction
mechanisms provided, interfaces, and configurable events to read inputs, process and send only valid selected information to the cloud.

4.5 REAL-TIME WEIGHTS COMMUNICATION USING WEB_SOCKET

The installed webcam allows for real-time viewing of the chicken's weighing process, but to validate the weighing algorithm and analyze exception situations, it was developed a real-time weight streaming mechanism to add this missing functionality on the cloud platform. It was used WebSocket, Amazon Elastic Compute Cloud (EC2), to create a Virtual Private Server (VPS) and a Windows Server 2016 instance and installed XAMPP to run an Apache HTTP Server and a lightweight Socket Server written in PHP.

![Data flow diagram.](image)

For the client-side, it was created an HTML5/CSS webpage to display a live chart using JavaScript (JS) and HighCharts, an SVG-based multi-platform charting library, side by side with the webcam image, presented inside an iframe HTML tag within a Farmcontrol cloud platform dashboard widget.

![Poultry live weighing on the Farmcontrol dashboard.](image)

Figure 5- Data flow diagram.

Figure 6- Poultry live weighing on the Farmcontrol dashboard.
5. FIELDWORK

5.1 SCALE INSTALLATION

The scale was installed in a poultry house, and the camera was mounted vertically about 2.5 meters high. Weighings were remotely monitored through images sent by the camera.

![Image of scale weighing two broiler chickens.](image)

*Figure 7 - Scale weighing two broiler chickens.*

The chickens adapted very well to the presence of the scale, being on the scale more than 85% of the time, and more than 60% of the time there were several chickens on the scale pan, with an average of about 30 valid chicken weighing per hour over the 14 days of the study.

![Graph of Scale Gross Weighings](image)

*Figure 8 - Scale readings without algorithm application.*

5.1 DRIVER SIMULATOR

The algorithm was rewritten in C Sharp to ensure that the driver that has been developed to run locally on the gateway works as expected. It was also developed a Windows application that uses the scale driver class with the Raw Input data, and also a timer to simulate the operation of the gateway, to check the accuracy of the processed weights.
Researchers reported poor agreement between automatic and manual mean weighing used as a reference [12]. Zootechnicians made manual weighing of 25, and 29-day-old broiler chickens, by random sampling. Significant weight differences between different weighings show the inaccuracy of the manual weighing method; on the other hand, the number of weighings required to obtain relevant statistical significance makes manual weighing impracticable. The method that offers the highest level of accuracy for obtaining average batch weights is the weighing of the loaded chicken truck on a truck weighing scale at the entrance to the slaughterhouse once the broiler chickens are recounted and the weighings are all documented with the weighbridge tickets.

Table 1 – Average body weights acquired by other means.

<table>
<thead>
<tr>
<th>Bird Age (days)</th>
<th>BWs Average (g)</th>
<th>Weighing Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>21</td>
<td>800</td>
<td>Manual</td>
</tr>
<tr>
<td>25</td>
<td>1,167</td>
<td>Manual</td>
</tr>
<tr>
<td>29</td>
<td>1,463</td>
<td>Manual</td>
</tr>
<tr>
<td>32</td>
<td>1,514</td>
<td>Truck Scale</td>
</tr>
<tr>
<td>33</td>
<td>1,563</td>
<td>Truck Scale</td>
</tr>
</tbody>
</table>

6. RESULTS

6.1 GRAPHICAL ANALYSIS OF RAW DATA

From the weighing data collected and using the driver simulator and the graphical data analysis application, several different patterns of broiler movement on the scale were found, some of them are presented below as an example:
Figure 10- On the left, one chicken climbed up and after 10 seconds climbed down. On the right, one chicken climbed up, and another one climbed down from the scale.

Figure 11- On the left, a chicken went up and (probably) flapped its wings. On the right, frenetic chicken movements.

6.2 BROILER CHICKENS WEIGHTS DISTRIBUTION

Many traits of animals show a normal distribution [13], which means that the distribution is symmetric and can be characterized by a mean and variance.

![Body Weights vs. Normal Distribution](image)

Figure 12 - Comparison of live BWs with the normal distribution curve at 32-day-old.
6.3 POULTRY SCALE ACCURACY

All collected weights were summarized in the chart below, allowing to compare the different weighing systems.

![Automatic vs. Manual Weights](image)

Figure 13 - Automatic acquired average BWs versus manual weighing.

The weights obtained from the scale over time are very close to a straight line, which can be confirmed by the value of the coefficient of determination (R² equal to 0.9953).

Table 2 - Average BWs, predictions, and errors.

<table>
<thead>
<tr>
<th>Age</th>
<th>Truck Scale</th>
<th>Predicted</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>32</td>
<td>1,514</td>
<td>1,496</td>
<td>-1.19%</td>
</tr>
<tr>
<td>33</td>
<td>1,563</td>
<td>1,558</td>
<td>-0.34%</td>
</tr>
</tbody>
</table>

From the table above, it can be seen that the differences between the actual weights and the predicted weights are well below the maximum objective error of 3%.

7. CONCLUSIONS

The acceptance of the scale by the chickens was remarkable; The scale was used more than 85% of the time, and 60% of the time with the presence of several chickens simultaneously. In the two weeks in which the study was carried out, 1 million weighings were made, and 8,706 body weights of broiler chickens were considered valid.

The differences between actual weights and forecasts, -1.19% and -0.34%, fully meet current broiler production requirements of 3% maximum error, confirming the automatic weighing’s system reliability. The results are good evidence that the traditional way of poultry weighing can be replaced by an automated embedded system.
with higher accuracy which gives the farmers the ability to have real-time monitoring, from any location, reducing time spent, human resources, costs, and improving productivity and quality in poultry farms.

**Further Work**

Since the weight of the birds may not be evenly distributed in the poultry house, considering birds are animals of territorial habits, the representativeness of the sampling could be improved if weighing was carried out at various equidistant points of the house. For such, a wireless scale would make it easier for its rapid displacement without interfering with the farmer production routines. The development of a long-term power autonomy independent wireless scale, based on the study made, requires a low power consumption load cells with a higher bridge resistance and hardware, with rechargeable batteries to allow uninterrupted operation of the scale during the whole life cycle (1 to 3 months) of the flock.

**References**


