Modelling of spatial variation of floor eggs in an aviary house for laying hens

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Abstract

A problem in loose housing systems for layers is laying eggs on the floor, which need manual collection. To automate this, it is desired to know the location of floor eggs for planning a collection path. As this information is not available, we constructed a spatial model to indicate the probability on floor eggs, based on housing properties. This model is mainly determined by parameters relating probability to position in the house. Validation against floor egg locations from poultry practice indicated that underlying model assumptions match with practice, making the model a suitable start for further work in this field.

Keywords: Alternative Poultry housing, Laying hens, Floor Laying, Floor Eggs, Laying Behaviour.

Introduction

History

The EC issued a ban on egg production in traditional battery cages by 2012. Alternative loose housing systems were developed, e.g. aviary systems containing multiple elevated tiers that maintained productivity while improving behavioural freedom and welfare for the animals. This also introduced problems, like the presence of floor eggs. Such eggs are laid on the floor, which is covered with litter for scratching and dust bathing. Floor eggs have a twofold influence on the farming practice: Yield is reduced due to degraded quality and lost eggs (which result from floor conditions and pecking by other animals) while demand for (manual) labour increases from the need to collect the eggs (Appleby, 1984; Emous *et al*., 2001). The presence of floor eggs mainly results from four factors: 1) Inability of the hen to reach the nest (Appleby, 1984; Emous and Fiks - van Niekerk, 2003); 2) A mismatch between the properties of the nest and the hens preferences (Zupan *et al*., 2008); 3) The unfamiliarity with laying, especially for younger hens (Appleby, 1984; Emous and Fiks - van Niekerk, 2003); 4) Presence of other eggs on the floor, inducing additive laying (Emous and Fiks - van Niekerk, 2003). All of these result in placing the egg outside the nest box, in the litter on the floor or on elevated tiers in the housing. As collection of the latter already can be automated, we focus in this paper only on floor eggs. Research already came up with three solutions: A) Appropriate training of the birds; B) Improvements in management of the farmer, housing layout and strain selection; C) Frequent collection of floor eggs to limit the chance on additional floor eggs (Emous and Fiks - van Niekerk, 2003). With these solutions, current poultry practice is able to reach floor egg percentages below 1%. However, it is expected that floor laying will remain, as a result of variation between flocks and specific preferences of the hens on their nesting places (Appleby, 1984; Zupan *et al*., 2008). Furthermore, this 1% remains a problem due to farm scale, labour costs and the labour demand to reach this level.

The problem

Since manual collection of floor eggs is a demanding task, recent advances in mobile robots (FRE, Darpa Challenges) gave rise to the idea of developing an autonomous vehicle for collecting floor eggs in commercial poultry houses. Benefits are reduction of the problem by more frequent collection of floor eggs and easing the farmer's work, without fixed installations in the poultry house. Main purpose of (manual) collection of floor eggs is to remove them as soon as possible to prevent laying of other eggs near these floor eggs. To fully exploit a mobile robot‘s capabilities, goal-oriented path planning is required, taking into account the spatial characteristics of the floor egg distribution. As neither such path a planning method nor a (formalised) model describing the floor egg problem exists, we developed and validated such a model.

Floor egg distribution

Past research mainly focused on the decrease of the total number of floor eggs. The amount of eggs and their exact locations are not described, only (Emous *et al*., 2001) gave explicit (but qualitative) information on the number of floor eggs on a limited number of specific locations. According to Van Niekerk (2013), hens search an enclosed and recognizable place, to feel safe and return there for the next egg. Farmers also indicate that in general, the more surrounded a location is, the higher the risk on floor eggs. This means that locations near walls and under interior elements and darker areas are preferred for floor laying. Besides, more animals will lay their eggs towards the front side of the housing (Emous and Fiks - van Niekerk, 2003).

The available knowledge and information seems sufficient to build a spatial egg distribution model based on qualitative relationships, but quantitative data for validation are missing. We hypothesize that it is possible to build a probabilistic model for a single multi-tier aviary house that describes the probability of floor eggs being present at each location, for a general situation without time- or flock specific aspects. We constructed such a model, tested the sensitivity of the model output for model parameters and validated the model results against spatial floor egg data gathered in practice.

Materials and methods

Model

On a laying hen farm in Opheusden, The Netherlands, two identical aviary houses were selected as reference situation for this research. Each house accommodated 36000 laying hens and was equipped with 5 rows of the Farmer Automatic Aviary (model year 2003, Farmer Automatic GmbH & Co. KG, Germany). A cross-section of the housing is shown in Figure 1, while a top view can be observed in Figure 2. On the four outer rows (A, B, D and E), Van Gent group laying nests (Van Gent International BV, The Netherlands) were provided. The front of the house was opposite to the wall where the ventilation fans were placed. The housing was longitudinally divided by mesh wire

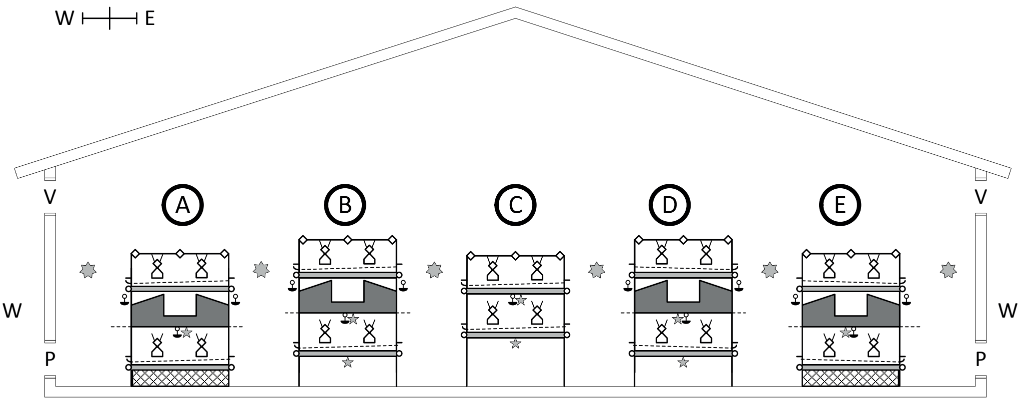

Figure 1: Cross-section of the reference poultry house. On both sides of the housing a Winter Garden (W) was present, accessible via pop holes (P). In the aviary house, rows with elevated tiers (indicated A to E) with feeding lines, drinkers, perches and laying nests were present. The whole floor was covered with litter for scratching and dust bathing, except for the rows on the outside (A and E), below which the floor area was not accessible

fences into six sections, which were considered to be equal and thus the model was developed for a single section only. The Winter Garden was not included in the model as hens only got access to the Winter Garden after laying. Spatial resolution of the model was 0.1 by 0.1 meter, which can hold approximately 1 egg at a time. For each location, a probability (P) between 0 (never a floor egg) and 1 (every day a floor egg) was calculated. The value of $P(floor\ egg)$ was determined by the housing layout, being the sum of three components, which are explained below: 1) distance to corners ($P_{corners}$);

2) shelter offered by a location ($P_{shelter}$); and 3) proximity of interior elements ($P_{proximity}$). It was expected that floor egg probability decreases with distance from a corner. Also, literature indicated that there might be slightly more eggs towards the front of the housing. Thus, it was decided to use an exponential decay function to determine the floor egg probability for each corner of a section separately and combine this to $P_{corners}$. The value for a single corner depended on the distance to the walls in *x* (cross sectional) direction and *y* (longitudinal) direction.

$$P_{corners}(x,y) = e^{-\left(\frac{x}{c_1}+\frac{y}{c_2}\right)} \tag{1}$$

Here *x* and *y* are distances in meters to the walls in the cross sectional and longitudinal direction respectively. Furthermore, model parameters *c1*=2.5 and *c2*=5 for corners on the front side of the house and *c1*=*c2*=2.5 for corners on the rear side of the house. Due to draught from the pop holes the origins of the corners were moved inwards in cross-sectional direction of the house, and the probabilities on the outside were lowered with a factor 10. By selecting the values for the weight factors, it was assured that the probability in the front was higher compared with the rear of the housing. The probabilities of the four corners were then combined according to:

$$P_{corners}(x,y) = \frac{\sum Front\big/_{0.8} + \sum Rear\big/_{2}}{1.3} \tag{2}$$

$P_{shelter}$ depended on the free height above a location (h_{free}). Literature indicated that enclosed or shaded areas favour floor laying, where less free height above a surface is a good indicator for more shelter and shade. Therefore, $P_{shelter}$ was determined by:

$$\begin{array}{lll} P_{shelter} = 0.2 & if & h_{free} < 0.4m \\ P_{shelter} = 0.15 & if & h_{free} < 0.7m \\ P_{shelter} = 0.1 & if & h_{free} < 1.0m \\ P_{shelter} = 0 & if & h_{free} \geq 1.0m \end{array} \tag{3}$$

With h_{free} the height in meters between floor and the obstacle above it.

$P_{proximity}$ accounted for the effect of interior elements in the proximity of a location in cross-sectional direction of the housing, which might favour the presence of floor eggs as well. This effect was modelled as function of the distance to the interior element:

$$P_{proximity} = (d_{max} - d) * c_3 \tag{4}$$

With *d* the distance to the object in meters, d_{max} the maximum distance to have effect (0.5m for walls and 0.3 for elevated tiers) and model parameter c_3 the contribution of the interior element (0.3 for walls and 0.2 for elevated tiers).

P(floor egg) now becomes:

$$P(floor\ egg) = P_{corners} + P_{shelter} + P_{proximity} \tag{5}$$

Finally, *P(floor egg)* was limited to 0.98, since it is never completely sure that an egg is found on a specific location. Furthermore, *P(floor egg)* was set to 0 for locations that could not be accessed by animals (row A and E). To represent the full housing, results of a single section were replicated six times to form a map of the complete house.

Model Sensitivity

To determine the sensitivity of the model for its parameters, their contribution was investigated using a full factorial sensitivity analysis (Montgomery, 2009; Snoek *et al*., 2012). This analysis contained all possible combinations of a high and low value (-50% and +50% of the original value) for each parameter. For 8 locations that represents areas with different properties (front, middle, rear, in corners and below elevated tiers) in the house, the contribution of model parameters and their interactions (up to 5 parameters) was assessed using a Sum of Squares measure. The locations can be found in Figure 2.

Model Validation

To validate the model, data was collected from the two reference poultry houses. In both houses, the location of each floor egg was recorded. Recordings were done once a week by a human observer which followed the farmer during his daily collection round, which took place between 9:00h and 11:00h. Floor egg locations were manually registered on a map of the house, consisting of 6 similar sections. On the map, each section was longitudinally divided into 39 cells of 0.4m, and crosswise into 38 cells of about 0.45m (see Figure 2). Data was collected on two flocks of white hens (Dekalb White) in two houses, from 30 until 34 weeks of age and from 40 until 44 weeks of age. Data from all recordings (over time) and sections (in space) were considered to be independent, and were combined in the analysis to form a single distribution for each measurement period of 5 weeks. Each distribution contains the sum of 2 houses, 6 sections per house and 5 observations in time.

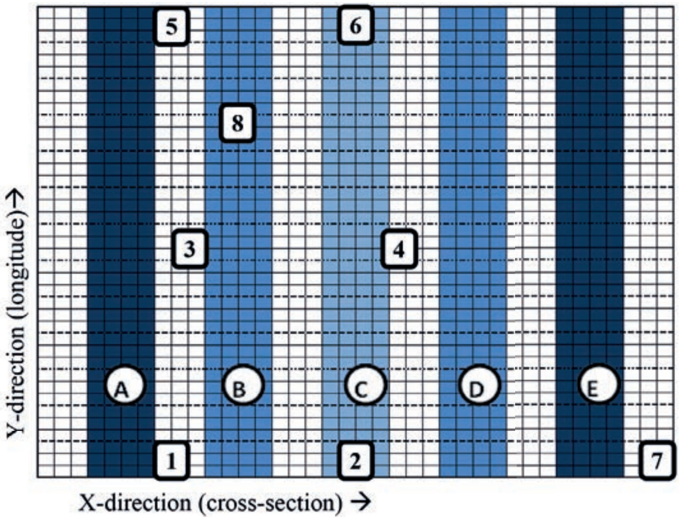

Figure 2: Map of a housing section, as used in the validation measurements. Letters A to E refer to the aviary rows in Figure 1, while the numbers indicate the locations that are evaluated in the sensitivity analysis.

Results

<u>Model</u>

Figure 3 shows the map produced by the model, where the aviary rows on the outside (A and E) are visible as the dark blue horizontal lines (*P(floor egg)*=0) and the six sections can be recognised as the replication of the pattern in horizontal direction. Furthermore, it can be seen that probabilities were highest in the front corners, as well as raised for locations below and near aviary rows.

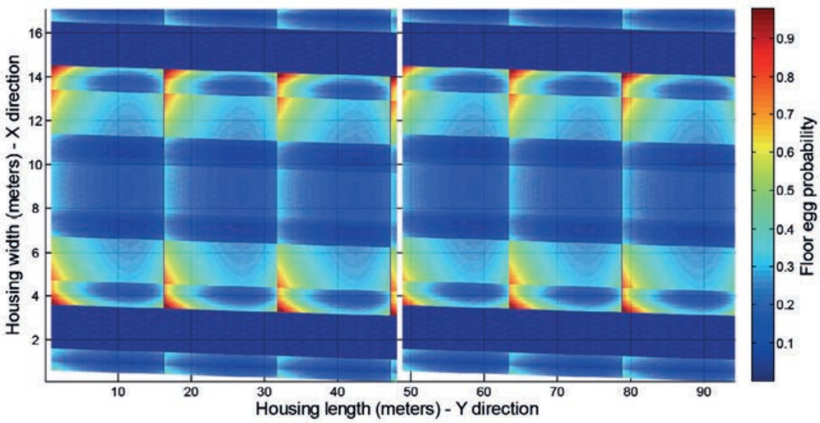

Figure 3: The map resulting from the floor egg model, indicating the probability on a floor egg for each location in the housing. The dark blue lines refer to A and E in Figure 1**.**

Model Sensitivity

Contribution of parameters is varying among the selected locations, but *P(floor egg)* is mainly determined by the parameters of $P_{corners}$, with a total contribution between 50% and 96%. In corners, locations 1 and 5, $P_{corners}$ is determined by the weight factors of the single probabilities, with contributions of 96% and 85%. On other locations factors determining the single probabilities, *c1* and *c2*, play a larger role with a contribution between 40% and 50%. For most locations, the contribution to *P(floor egg)* of parameters from the front is larger than from the rear. Elevated tiers, walls and obstacles had a limited contribution of less than 5% to *P(floor egg).* Only for locations with a low probability from $P_{corners}$, like location 8, they showed a higher contribution which is reaching almost 30%.

Model Validation

Validation results can be found in Figure 4 and Figure 5. To match model output with measurement results, the probability distribution in the model was converted into the expected floor egg distribution. Figure 4 shows the floor egg distribution along the cross section of the house, which qualitatively matched the model rather well. Highest numbers, between 4 and 11%, were found on the outside of the litter area (between rows A-B and D-E) and below elevated tiers with limited height (rows B and D). Lower numbers of less than 1% were found in the middle region and in the outside corridors. Figure 5 shows the floor egg distribution in longitudinal direction, with considerable

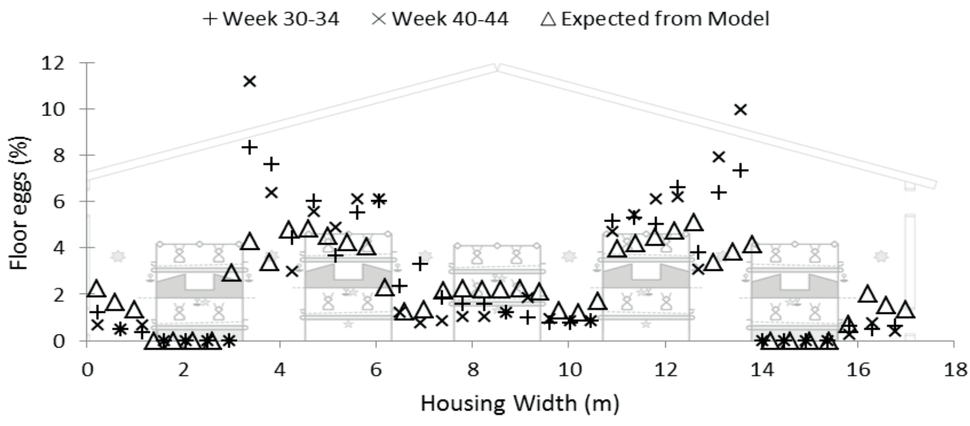

Figure 4: Distribution of floor eggs as percentage of total floor eggs along cross-section of the house. Data was collected in two periods of 5 weeks. Series names indicate animal age in weeks during these periods.

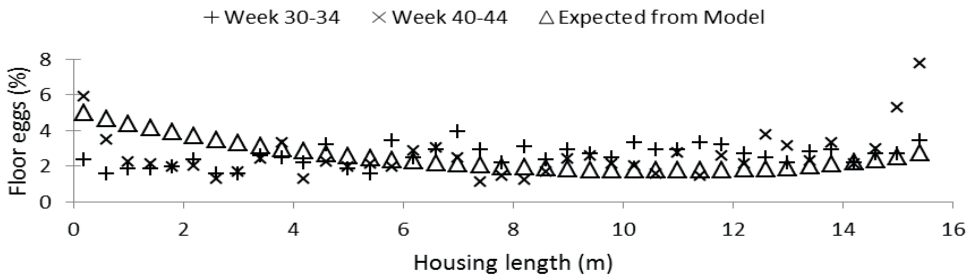

Figure 5: Distribution of floor eggs as percentage of total floor eggs along longitudinal direction of the house. Data was collected in two periods of 5 weeks. Series names indicate animal age in weeks during these periods

variation around a certain level (about 2% for each location), and an increase at the front and rear of the house (especially for Week 40-44). Furthermore, it can be observed from both figures that the distribution has shifted between the two measurement series.

Discussion

<u>Model</u>

The probability model was constructed based on qualitative knowledge and calibrated intuitively. Therefore the assumptions taken, for example on the chosen representation (a probabilistic model), might be discussed as other representations might yield better results. The same holds for the initial choice of parameters, functions and parameter values that are used in this model to construct to *P(floor egg)*. However, the results of the used model match well to the available literature and findings in practice, making the model suitable for further use. Still, we recommend more research on the choices that have been made, to ensure the correctness of the model.

<u>Model Sensitivity</u>

The results of the sensitivity analysis match with expectations, in that location within the house ($P_{corners}$) contributed most, followed by the effect of shelter ($P_{shelter}$). Selection of parameter values determining $P_{corners}$ needs to be done carefully, since $P_{corners}$ contributes over 50% to the probability on floor eggs. A further check on the correctness of these values is thus advised. The limited effect of obstacles ($P_{proximity}$) on the probability indicates that their role in the model needs more attention. This can be done in two ways: by increasing the effect or by removing this parameter from the model. Both require an evaluation of the role of obstacles on the floor egg probability.

Model Validation

With respect to the validation experiment, it should be noted that only a single housing type with a single animal breed was tested during a short period with a very low percentage of floor eggs (0.3% ≈ 2000 eggs collected in the experiment). Performing experiments on a larger scale might give a more representative result. However, measurement results agree qualitatively with available literature and practical experiences, indicating that observations resemble common poultry practice.

The conversion from model probability to expected floor egg distribution has introduced some round-off errors, so that some of the values in the graph are lower compared to the real model. Also the resolution of the sampling map should be noted here, which was taken as small as practically feasible. As there was no exact position measurement, floor egg locations were registered with a deviation from reality of less than 0.3 meter. This resulted in loss of specific information, like the presence of clusters over multiple cells or the exact location of an egg within a cell. Both were observed during the measurement but partly disappeared in the measurement map as result of its resolution. Thus, higher accuracy in the registration might have slightly changed the distribution (without affecting the results or the model), most likely by placing the location of the eggs more close to the obstacles and indicate a certain degree of clustering of the eggs. The personnel on the reference farm confirmed that the probability model qualitatively described the distribution of the floor eggs in a general way. Still, for each flock adaptations might be required to resemble their specific behaviour.

This holds also for the application of management measures like the use of (electric) fencing. Adaption might also be required to account for variation over time, as can be observed from the shift in distribution between the first and second measurement period shown in Figure 4 and Figure 5. Thus, adding adaptability on flocks and over time is highly recommended, especially when using this model for planning floor egg collection paths and other practical applications.

Conclusion

It was possible to build a model describing spatial floor egg distribution by 3 components: 1) Position in the poultry house; 2) Free height above the floor; 3) Proximity of obstacles. These components were combined in a model resembling floor egg probability with a value between 0 and 1. The floor egg probability in the model is mainly determined by the position in the poultry house (1). Less dominant are free height above the floor (2) and distance to interior elements (3). The validation experiment shows that the model qualitatively agrees with the spatial floor egg distribution found under practical circumstances. The model is more than sufficient to be used in the evaluation of floor egg collection paths.

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