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Research Paper

Path planning for the autonomous collection of eggs on floors

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A problem in loose housing systems for laying hens is the laying of eggs on the floor; these eggs need manual collection. This job is heavy and time-consuming and automated collection is desired. For collection using a robot, a collection path is required. A novel path planning algorithm is introduced for non-uniform repetitive area coverage (NURAC) paths and evaluated based on information about floor egg distribution probability. Firstly, a spatial map was developed that describes the potential for floor eggs at each location in a poultry house. Next, paths for floor egg collection are planned with a dynamic programming approach that covers the house floor area and frequently revisits locations with a high potential on floor eggs. These paths are compared with the paths used for floor egg collection by a farmer and evaluated with help of a simulated set of floor eggs. With respect to the average time eggs are present on the floor, paths planned for a robot are compared to two collection rounds of a farmer. With respect to the structure of the path and the number of visits to locations with a high potential, the robot paths outperform the farmer. Although optimality of the path is not guaranteed, the presented results are promising for the use of a robot to collect floor eggs, and will result in a reduction of the demand for manual labour. Extending the floor egg model with feedback information could further improve the results.

1. Introduction

1.1. Floor eggs

Based on the increasing concerns of the public about the welfare of production animals, the EC issued a ban on egg production in traditional battery cages by 2012 (European Union, 1999). Since the 1980's, this led to a search for alternative systems, categorised as enriched cages or colony systems and loose housing systems. The basics of the latter type are centuries old but to comply with modern farming practice improvements in scale and productivity were necessary. As a result, the aviary system was developed (see Blokhuis & Metz, 1995; Sandilands & Hocking, 2012) which increased productivity while maintaining freedom of behaviour for the animal.

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Nomenclature

μ	Mean
a	Instance of length index
b	Instance of width index
C_k	Contribution at stage k
c_1–c_4	Constants controlling the incentive function
Egg time	Time an egg is present on the floor, h
f	Factor controlling the yield increase
I	Number of cells in length of the house
i	Cell index in length direction
J	Number of cells in width of the house
j	Cell index in width direction
k	Index of cell transition or stage
L	Total set of locations
$L_{i,j}$	Location i,j, with $i = 1{:}I$, $j = 1{:}J$
N	Number of cell transitions
O	Optimisation criterion
$P_{i,j}$	Floor egg potential at location i,j
$P_{i(k),j(k)}$	Floor egg potential at location i,j at stage k
$R_{i,j}$	Incentive at location i,j
$R_{i(k),j(k)}$	Incentive at location i,j at stage k
T_k	State transition at stage k
t	Time, h
$t_{collection}$	Time of collection of an egg, h
t_{lay}	Time of lay of an egg, h
U	Set of possible transitions or decisions
u_k	Decision at stage k
V_k	Value function at stage k
X	Width direction of the house
x_k	State at stage k
Y	Length direction of the house
$Y_{i,j}$	Yield at location i,j
$Y_{i(k),j(k)}$	Yield at location i,j at stage k
Y_{max}	Maximum yield
σ	Variance

In these systems hens are trained and expected to lay their eggs in the nests; However, a significant portion can be found at other places such as elevated tiers and the floor (either litter or slatted floors) and these eggs are called ‘mislaid eggs’.

Laying of eggs outside the nests is induced by factors such as the inability of the hen to reach the nest, unfamiliarity with laying (especially at a younger age), conceptual mismatch between the properties of the nest and the expectation of the hen and presence of other eggs outside the nest (Appleby, 1984; Zupan, Kruschwitz, Buchwalder, Huber-Eichter, & Stuhec, 2008). Eggs laid in the litter on the floor are considered to be a problem in poultry farming. They have a lower quality due to contamination by the litter and they induce additional floor laying. Thus frequent collection of floor eggs is required (Abrahamsson & Tauson, 1998; Appleby, 1984; Emous & Fiks-van Niekerk, 2003; Emous, Reuvekamp, & Fiks-van Niekerk, 2001). Research has been done on measures to reduce the laying of floor eggs. This has led to specific adaptations of the housing systems and a series of management and control measures used by farmers. None of them has proven to be completely successful (Abrahamsson & Tauson, 1998; Appleby, 1984; Cooper & Appleby, 1996a, 1996b; Emous & Fiks-van Niekerk, 2003; Gunnarsson, Keeling, & Svedberg, 1999; Lundberg & Keeling, 1999; Tauson, 2005; Zupan et al., 2008). One of the key control measures taken is the frequent manual collection of floor eggs. This is a physically demanding job under harsh environmental conditions and it can take up to 37% of the work time of the farmer (Blokhuis & Metz, 1995; Drost & van der Drift, 1993; van den Top, Akkermans, & Oude Vrielink, 1994).

1.2. Egg collection

To ease this collection task, for instance, a gripper stick, an automated collection system with a rake (Fiks-van Niekerk, Reuvekamp, van Emous, & Ruis, 2003) and the Chicken Trolley (“Chicken Trolley,” 2010) have been proposed. However, despite the enormous progress already made, it is expected that the problem of floor laying will remain with current systems, as a result of variations between flocks and the specific preferences of the hens with respect to their nesting places.

Another alternative is to use an autonomous multi-functional robot platform for the collection of floor eggs. It could also be used for the monitoring of indoor climate, identifying dead hens, monitoring animal behaviour and welfare and perform other tasks thereby alleviating the work of the farmer, without the need for a fixed installation in the poultry house. This idea builds on a robotic platform that was constructed for the Field Robot Event competition of 2007 (Proceedings 5th Field Robot Event, 2007). In the free-style task of that competition, an autonomous robot with a collection device demonstrated the collection of floor eggs (Kool, Vroegindeweij, Wollerich, & van der Zwaag, 2007). The basic idea was well received in agricultural practice in The Netherlands (Bijleveld, 2007).

As a result a research project started in 2011 at Wageningen University focussing on the development of such an autonomous multi-functional platform. To ensure safe and correct functioning of such a platform, essentially, the following functions need to be implemented (Bechar, 2010), 1) mobility, steering and control, 2) sensing, 3) path planning and navigation, 4) manipulators and functional devices to deal with products, and 5) intelligence and autonomy.

1.3. Path planning methods

This paper addresses the path planning for such a platform focussing on floor egg collection. The path planning algorithm had to take into account that floor eggs are non-uniformly distributed with respect to space (the location in the aviary house) and time (the moment the eggs are laid). Given these characteristics, key requirements for the path planner were: 1) the time that eggs lie on the floor should be minimised to prevent loss of quality; 2) the robot should cover the whole aviary house in 24 h; 3) the robot should be able to exploit the