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Research Paper

Evaluation of the performance of PoultryBot, an autonomous mobile robotic platform for poultry houses

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Assessment of animal status, housing conditions and manually collecting floor eggs are the major daily tasks for poultry farmers. To assist the farmer in these tasks, PoultryBot, an autonomous mobile robot for use in poultry houses has been developed. In earlier research, several components of PoultryBot were discussed in detail. Here, performance of the robot is evaluated under practical conditions. For navigation, different paths were used to assess its navigation performance for various tasks, such as area sweeping and surveying close to walls. PoultryBot proved capable of navigating autonomously more than 3000 m, while avoiding obstacles and dealing with the hens present. The robustness of its navigation performance was tested by confronting PoultryBot with obstacles in different positions with respect to its path and using different settings of the navigation parameters. Both factors clearly influenced the driving behaviour of PoultryBot. For floor egg collection, detection and collection of eggs was assessed at 5 predefined egg positions lateral to the path of the robot. Over 300 eggs were tested; 46% were collected successfully, 37% was not collected successfully, and 16% were missed. The most observed failures occurred when the collection device was just next to the egg. It is thought that this problem can be solved by improving the control algorithm. The results demonstrate the validity of the PoultryBot concept and the possibility of autonomous floor egg collection in commercial poultry houses. Furthermore, they indicate that application of smart autonomous vehicles in dense animal environments is feasible.

1. Introduction

In an era where automation and the use of robots is increasing, opportunities arise also to take over the repetitive or dirty tasks currently found in livestock farming. One of the major daily tasks of every poultry farmer, is observing and checking the health and well-being of the animals, and making sure all housing and control systems function properly. Due to the

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Nomenclature

FN	False Negative
FP	False Positive
TN	True Negative
TP	True Positive
FDR	False Discovery Rate

increase of sizes of farms, the time available per animal for observational tasks has decreased. At the same time, with changes in housing the behavioural freedom for the animals has increased. This has led to an increased need for flock observation and management since animal status now has a larger impact on production. Having a mobile platform that moves autonomously among the animals all day long provides the poultry farmer with more and potentially more objective information about the animals and their environment.

Besides information gathering, there is a growing interest in using automatic floor egg collection in the modern animal-friendly loose housing systems adopted for laying hens. Floor eggs originate from animals that prefer to lay their eggs in some other location rather than the provided nest space. Based on extensive research (like Blokhuis & Metz, 1995; Froehlich & Oester, 2001; van Niekerk & Reuvekamp, 1997), farm management has improved significantly in recent decades. Combined with improved animal training, this has greatly reduced the number of floor eggs.

However, despite proper animal training and management, these floor eggs still account for 0.1%–2% of the daily production. In extreme cases, the number of floor eggs can even increase to 5%–10% of total egg production. In all cases, the required manual collection of these eggs puts a significant load on the daily activities of the farm staff (Blokhuis & Metz, 1995; Claeys, 2007).

As part of the research project "Automation for Poultry Production" at Wageningen University, the first autonomous poultry house robot (PoultryBot), was developed to help the poultry farmer in his daily work in the modern aviary poultry house. More specifically, floor egg collection was used as an example case in the development and evaluation of PoultryBot. For floor egg collection, PoultryBot should move freely throughout the whole poultry house, while being aware of its location in the house and the location of nearby obstacles. Furthermore, the robot should be able to detect and collect floor eggs, regardless of their location in the poultry house.

Several other applications exist where robots were freely acting in a complex environment, including interaction with dynamic objects such as humans, animals or plants. For example, the robots Rhino and Minerva acted as tour guides in museums (Burgard et al., 1999; Thrun et al., 2000), while Spencer guided passengers in an airport terminals (Triebel et al., 2015). In the agricultural domain, which is characterised by its complexity and limited structure (Nof, 2009), significant effort has been spent on autonomous robots for field work (Bakker, 2009; Deepfield Robotics, 2016; Hiremath, Evert, Heijden, Braak, & Stein, 2012) but also in orchards or greenhouses (Bac, van Henten, Hemming, & Edan, 2014; Bayar, Bergerman, Koku, & Konukseven, 2015; Shalal, Low, McCarthy, & Hancock, 2015a,b). Several of the methods used in developing these robots can be considered as being useful for PoultryBot, such as the particle filter for localisation and the vision approaches used for fruit detection in horticulture (Bac, Hemming, & van Henten, 2013; van Henten et al., 2002). Their usefulness in the challenging environment of an aviary poultry house, however, still had to be proven.

With respect to livestock farming, some simple autonomous vehicles with fixed paths are used in dairy husbandry (Lely, 2015). In the domain of intensive animal production, a few research activities have been carried out, such as a student project at the KU Leuven, Belgium (Aertsen et al., 2012), some preliminary investigations on a mobile monitoring robot from Australia (Qi, Brookshaw, Low, & Banhazi, 2013; Haixa Qi et al., 2013) and a project on monitoring animal health and well-being using mobile and aerial robots at the Georgia Institute of Technology, USA. PoultryBot can be differentiated from previous examples of livestock robots by: 1) having more advanced systems for localisation and navigation, such that it can move freely and goal-driven throughout its environment; 2) being able to detect and interact with objects of interest; 3) being a test bed for an integrated system in a practical poultry house.

Previous work has introduced the concept of PoultryBot, and described and evaluated several of its main features. In Vroegindeweij, Ijsselmuiden, and van Henten (2016), a localisation system based on the particle filter approach (Thrun, Burgard, & Fox, 2005; Thrun et al., 2000) that originated from museum robot Minerva, was described and evaluated in a poultry house without hens. Vroegindeweij, van Willigenburg, Groot Koerkamp, and van Henten (2014) addressed the problem of path planning for the collection of floor eggs by presenting a new algorithm for non-uniform repetitive area coverage, when to the best of our knowledge, no such method existed at that time. Based on the use of multispectral features for fruit detection in harvesting robots from horticulture (Bac et al., 2013; van Henten et al., 2002), Vroegindeweij, van Hell, IJsselmuiden, and van Henten (2018) presented and tested an approach for the discriminating between the various object types in the poultry house that are relevant for the functioning of PoultryBot. Finally, in Vroegindeweij, Kortlever, Wais, and van Henten (2014), a description and evaluation of an actuator for floor egg collection was presented. Therefore, while individual aspects of this robotic system have been tested, to prove that the proposed concept and methods work, they have to be tested in an integrated manner under (near) practical conditions.

The objective of the current paper is to evaluate the performance of PoultryBot in a near practical environment. As an initial performance benchmark, a number of requirements for a future implementation of PoultryBot in commercial poultry houses can be indicated. Firstly, the robot should be able to operate autonomously, such that human intervention of the farmers are hardly required. To achieve this, it should drive collision-free through the poultry house, while being capable of handling various path types, such as traversing large areas to move from spot to spot or driving close to a wall to reduce floor laying in these areas. Furthermore, as object density in the poultry house is high and floor eggs can be found close to