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Research Paper

Object discrimination in poultry housing using spectral reflectivity

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To handle surrounding objects, autonomous poultry house robots need to discriminate between various types of object present in the poultry house. A simple and robust method for image pixel classification based on spectral reflectance properties is presented. The four object categories most relevant for the autonomous robot PoultryBot are eggs, hens, housing elements and litter. Spectral reflectance distributions were measured between 400 and 1000 nm and based on these spectral responses the wavelength band with lowest overlap between all object categories was identified. This wavelength band was found around 467 nm with an overlap of 16% for hens vs. eggs, 12% for housing vs. litter, and less for other combinations. Subsequently, images were captured in a commercial poultry house, using a standard monochrome camera and a band pass filter centred around 470 nm. In 87 images, intensity thresholds were applied to classify each pixel into one of four categories. For eggs, the required 80% correctly classified pixels was almost reached with 79.9% of the pixels classified correctly. For hens and litter, 40–50% of the pixels were classified correctly, while housing elements had lower performance (15.6%). Although the imaging setup was designed to function without artificial light, its optical properties influenced image quality and the resulting classification performance. To reduce these undesired effects on the images, and to improve classification performance, artificial lighting and additional processing steps are proposed. The presented results indicate both the simplicity and elegance of applying this method and are a suitable starting point for implementing egg detection with the robot.

1. Introduction

In current poultry production systems in Western Europe, and more and more in other parts of the world, laying hens in commercial farms have more freedom to move around in their living environment. Compared to earlier cage housing this requires more advanced management and more human labour under unfavourable conditions, for example for the collection of floor eggs (Blokhuis & Metz, 1995; Claeys, 2007). In earlier work (Vroegindeweij, van Willigenburg, Groot

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Nomenclature

TP	True positive, i.e. correctly classified as object
TN	True negative, i.e. correctly classified as non-object
FP	False positive, i.e. incorrectly classified as object
FN	False negative, i.e. incorrectly classified as non-object
TPR	True positive ratio, ratio of TP divided by TP + FN
FPR	False positive ratio, ratio of FP divided by FP + TN
T1	Threshold 1, separating litter and housing
T2	Threshold 2, separating housing and hens
T3	Threshold 3, separating hens and eggs
GT	Ground truth
ROC	Receiver operating characteristic
R	Measured spectral reflectance after correction
I	Measured spectral intensity
B	Black reference, relates to sensor noise
W	White reference, relates to full exposure of sensor
FWHM	Full-width half maximum, property of spectral filter
FPS	Frames per second, speed of camera shutter
F-number	Relative aperture of lens
PCA	Principle component analysis
LDA	Linear discriminant analysis

Koerkamp, & van Henten, 2014), a poultry house robot (designated *PoultryBot*) that will assist the farmer in such tasks was introduced. For this robot, path planning and localisation methods were previously presented and evaluated (Vroegindeweij, Ijsselmuiden, & van Henten, 2016; Vroegindeweij, et al., 2014). In addition to knowing their location and following a desired path, autonomous poultry house robots should also be aware of objects in their surroundings, especially those objects that affect their functioning, such as hens, poultry house elements and eggs. As the required response to such objects differs between object types, objects should not only be detected but also be classified into different categories. In robotics, vision-based methods are commonly applied for such detection and discrimination of objects (Bac et al., 2017; Ball et al., 2016; Ekvall, Kragic, & Jensfelt, 2007; Pillai & Leonard, 2015). Thus, the aim of this research was to investigate if vision based methods are suitable for creating environmental awareness for an autonomous poultry house robot.

A poultry house is a challenging environment for a robotic system with sensing based on camera vision. For details on the layout and properties of aviary poultry houses the work by Blokhuis and Metz (1995), Sandilands and Hocking (2012), and Vroegindeweij et al. (2016) is recommended. The houses are in general rather dark, with light intensities varying between 5 and 30 lux (Ellen, van Emous, & Kruit, 2007; Prescott & Wathes, 1999). In general, fluorescent or LED sources provide white light with a fairly flat spectral distribution. However, as light colour is used to control animal behaviour, light sources with different colours can be used, and light colour can change in the poultry house within a single production cycle (Ellen et al., 2007; Lewis & Morris, 2000).

An additional challenge for camera vision is the fact that aviary poultry houses are densely populated with metal housing objects that offer various facilities to the animals. The remaining free space is occupied by tens of thousands of animals that move around at will. Finally, the ambient air contains high concentrations of dust and vapour. All of this reduces clear and free sight and leads to continuous variation in image content.

As a first step in the development and evaluation of a vision system for this application, the aim was to detect and classify of objects at pixel level. For image classification and object detection, a simple method was preferred since that would reduce the computing power required for image processing and would not require additional lighting which would avoid undesirable influence on animal behaviour. As an initial objective, correctly classifying 80% of pixels was set as a target. Correctly classifying 80% of the pixels would mean that all objects are at least partially classified correctly, which was expected to be satisfactory for operating PoultryBot.

A relatively simple way to detect and identify objects in an agricultural scene is to exploit the differences in spectral reflection properties of the various objects present in the scene. Based on prior acquired reflection properties of the most common objects in such a scene, common and cheap monochrome cameras can be equipped with suitable filters to provide an image that may require less processing for object detection and classification.

This method has been used in agriculture to distinguish between various kinds of green plants (Nieuwenhuizen, Hofstee, van de Zande, Meuleman, & van Henten, 2010; Piron, Leemans, Kleynen, Lebeau, & Destain, 2008) and to distinguish between fruits, leaves and stems in cucumber harvesting (van Henten et al., 2002). A literature review revealed that spectral reflection properties have also been investigated before in poultry farming. Prescott and Wathes (1999) have presented an extensive review of reflective properties of poultry, their housing and the light characteristics therein. They presented results of 15 hen species, of which several are closely related to current commercial hybrid species. Furthermore, they showed spectral properties of various materials present in commercial poultry houses, which turned out to be distinct from the spectral properties of hens. Spectral characteristics of hen eggs were used mainly for transmission measurements to determine the quality of shelled eggs (De Ketelaere, Bamelis, Kemps, Decuypere, & De Baerdemaeker, 2004; Mertens et al., 2010). Less work has been done on spectral reflectance of eggs. In Prescott and Wathes (1999), only the spectral reflectance of a brown egg was reported. Gloag, Keller, and Langmore (2014) presented also work on other egg colours, although from a different bird, but with similar results.

This paper investigated the hypothesis that the spectral features of objects commonly found in poultry houses could be used for discriminating between these objects by PoultryBot. The laboratory experiment described in Section 2