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An automated positioning system for monitoring chickens' location: Accuracy and registration success in a free-range area

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ABSTRACT

Free-range use in chickens is often suboptimal, and the full potential of outdoor access for chicken welfare may not be achieved. Many studies use visual observations of free-range use, imposing several limitations. An automated system capable of continuously monitoring the location of multiple individual birds over a long time period has the potential to increase the amount and accuracy of the gathered data. Therefore, the aim of this study was to test a newly developed Ultra-Wideband system for monitoring the position of chickens with free-range access. This system consists of active tags (attached to the chickens) that send signals to anchors positioned at fixed locations in the field; the tags' position can be calculated using the time of arrival of their signal. The effects of vegetation type, precipitation, tags being mounted on a chicken, tag height, angle and orientation, coverage by A-frames or mobile chicken houses, and proximity of other tags on accuracy of the registered positions (distance between the registered and the true position of the tag) and on registration success (percentage of registrations where a position could be calculated) were assessed. Overall, the median error was 0.29 m, which was below the aim of 0.5 m, and the mean percentage of successful registered positions was 68%. None of the variables had a clear effect on the accuracy of the positions. Errors were generally larger in certain areas of the experimental field, which may be due to the asymmetrical setup of the anchors. The percentage of successful registrations was negatively affected by shelter type, with lower percentages in dense vegetation (short rotation coppice willows; SRCW) than on grassland, possibly due to malfunctioning of two anchors close to the SRCW plots. Rain and placing the tags underneath a wooden A-frame, but not placing them in a mobile house, resulted in a lower percentage of successful registrations. The tag being mounted on a chicken, height and angle of the tag and proximity of other tags had no negative effect on the percentage of successful registrations. Placing more (functioning) anchors may contribute to better accuracy and registration success. Alternatively, the bias resulting from the variables that had a negative effect on registration success could be corrected for when using the system in its current setup. Overall, this system shows great promise for monitoring chickens' free-range use.

1. Introduction

Chickens' free-range use, and what factors could play a role in improving it, are much studied topics (e.g. Dal Bosco et al., 2014; Fanatico et al., 2016; Pettersson et al., 2016; Stadig et al., 2017a,b; Stadig et al., 2017). Most studies use visual observations by researchers to quantify free-range use, but these have several disadvantages. The presence of an observer may disturb the animals, the observations are time-consuming and often result in a limited amount of data, accuracy of the data may not be optimal (e.g. it is difficult to determine the exact location of the animal in the range) especially when vegetation or other structures impede visibility, and it is difficult to monitor large numbers of individual animals. Studying individual animals is especially challenging in commercial situations since chickens are often kept in very large

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groups (thousands or tens of thousands of animals). The possibility to monitor individuals is valuable because it enables linking individual free-range use to other individual measures such as welfare, personality, and meat quality. It also enables studying differences between individuals, and underlying reasons for these differences. This way, the reasons for and effects of low or high free-range use can be studied more accurately.

An increasing number of studies are making use of automated techniques to monitoring free-range use, such as Radio-Frequency Identification (RFID), which measures if a bird is close to or crosses an antenna. The antenna is in the case of free-range studies usually placed in the pop hole so that it can monitor if the bird is inside or outside (e.g. Gebhardt-Henrich et al., 2014; Hartcher et al., 2016; Campbell et al., 2016). Alternatively, back-mounted light sensors can be used to determine if a bird is inside or outside based on the light intensity (Buijs et al., 2017). A limitation of RFID or light sensor technologies is that they register whether the bird is inside or outside, but not its exact position. Birds can for instance remain close to the house resting, while they are recorded as using the free range. Monitoring the exact position of the birds can be used for many purposes, e.g. for calculating the distance to the house or to their closest conspecific, which can be used for social network analysis, for monitoring time spent in distinct outside areas, which can give indications of preferences for range design, or for monitoring distance travelled. Automated positioning systems (APS) have already been used in other livestock species such as dairy cows (Backman et al., 2015). Using an APS outside imposes several possible difficulties, such as the expected negative effects of water (Deak et al., 2010), meaning that e.g. rain, chickens or vegetation could hamper signal transmission.

In the current study, an APS based on Ultra-Wideband (UWB) technology was developed in order to track chickens' position in a free-range area. This system was custom-built for the experimental field. The goal was to achieve a median accuracy of 50 cm or better. Therefore, the aims of this study were to test accuracy and registration success under different conditions, including different shelter types on the free range (dense vegetation or grassland with artificial shelters), weather conditions (dry or rain), proximity of multiple other tags (to resemble chickens sitting close together), height and angle of the tag (to resemble different chicken positions such as sitting and standing), orientation of the tag, being covered by artificial shelters or mobile chicken houses, and the tag being worn by a chicken. These factors were studied because, if they have an effect, they could possibly result in a bias in future studies on this experimental field, and likely also in other studies using similar technology.

2. Materials and methods

2.1. Positioning system

An UWB system was used to monitor chicken positions on an experimental field, used as a free-range area for chickens, at ILVO (Flanders, Belgium; Fig. 1). This system was developed by Sensolus (Ghent, Belgium). The system works with active tags (75 × 49 × 17 mm, 36 g), meaning that the tags have a battery and send out a signal to receivers or "anchors". These anchors are placed on fixed positions on the field. Based on the time of arrival of the signal, the distance between the tag and the anchor can be calculated. If a tag's signal is received by at least three of these anchors, its position can be calculated (the intersection of the three circles that can be drawn around the anchors at that distance). We only worked with 2D positioning. The system is capable of generating Z coordinates as well, but this is more difficult because it will generate more possible intersections between the circles, or globes in this case, around the anchors. Nine anchors were placed on the experimental field (Fig. 1), however the two anchors at the corners of the plots with dense vegetation (see 2.2) malfunctioned and did not contribute to the registration of tags' positions. A tag, its casing and the backpack which was used to attach it to the chicken are depicted in Fig. 2. The effects of wearing these backpacks on the chickens' behaviour, weight gain and leg health were assessed in a separate study (Stadig et al., 2017c). During all tests described here, the update rate of the tags was set at 1 Hz, i.e. a signal was sent out and a position should be registered every second. The data were recorded and stored locally using a desktop app developed specifically for this system.

2.2. Experimental field and animals

All tests were conducted on the experimental field shown in Fig. 1, in October and November 2016. This field contained four mobile chicken houses (4.1 × 4.25 m; McGregor Polytunnels Ltd., Ropley, UK; Fig. 3), which consisted mainly of plastic materials with an aluminium frame. The free-range areas consisted for 50% of grassland with 21 artificial shelters (wooden A-frames; AS; l × w × h: 2.5 × 1.25 × 1.5 m; Fig. 3), and for 50% of short rotation coppice with willows (SRCW; Fig. 3). SRCW was planted in 2013, in double rows, with 150 cm between two double rows, 75 cm between the two rows within a double row, and 60 cm between each tree within a row. During the time of testing the mean height of the trees was 6.6 m, and although leaf fall had commenced there were still leaves on the trees (the majority was still on in October, decreasing over time until leaf fall was completed in December). For the tests involving chickens, 42 70-day old slow-growing broiler chickens (Sasso XL451) were used. All experiments were approved by the ethical committee of the ILVO.

2.3. Accuracy and registration success tests

To test the accuracy (i.e. the difference between the position registered by the UWB system and the true position of the tag) and registration success (in this case: the percentage of successful registrations, see 2.5) of the system, tags were placed at fixed positions on the field in different configurations, depending on what was being tested. Table 1 gives an overview of all situations that were tested. Most tests were repeated for all four 'subfields' (the triangular fields in Fig. 1, with a mobile house in their centre), identified by the number of the mobile house on that subfield. All tests lasted for 1 min. The locations that were used for the tests are shown in Fig. 1. For the 'straight line' tests the tags were positioned 5 m apart from each other on the boundary of grass and SRCW, and 1 m towards each side onto the grass and the SRCW. This was done because we wanted to know how well chickens would be detected on this border between grass and SRCW, in order to perform shelter type preference tests in the future. For the 'diagonal line' tests the tags were placed on two diagonal lines (one on grassland, one in SRCW) which stretched between the central corner and the edge of the subfield. This was done in order to test the effect of shelter type. This test was repeated with the tags on the grass being covered by A-frames. For the tests located '10 cm from wall of house' tags were placed at each corner and in the middle of each side of the house, both indoors and outdoors (all 10 cm from the wall). The same was done for the '30 cm from wall of house' tests, but then with tags placed 30 cm from the walls (Fig. 1). This was done to test if the proximity of a mobile house would influence the system's performance, taking into account that chickens spend much time in or just outside the house. For the 'grouped together' tests, all tags were placed together (ca. 5 cm apart), once on the grass and once in the SRCW (both at the position on the diagonal line closest to the central corner of the triangular subfield). This was done because chickens often flock together, and it was unknown if many tags in close proximity of each other would influence accuracy or registration success.

For the tests without chickens, the tags (in their casing and backpack) were placed on plastic boxes, which were subsequently placed on known positions on the field. The boxes' dimensions were 12.5 × 20 × 34 cm, so that the tags could be placed at both 12.5 and