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Accuracy and validation of a radar-based automatic local position measurement system for tracking dairy cows in free-stall barns

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Abstract

A local position measurement system based on radar technology was set-up in a dairy cow free-stall barn. This system could potentially track up to 16,000 individual objects at a frequency of 300 position estimates/s. We describe the general steps for achieving positioning estimates and the transponder developed to be suitable for dairy cows. Measurements at fixed positions and data of dynamic circular measurements are provided, showing that estimates of the location of a transponder were within $\leq$0.5 m, regardless of whether it was moving or not. Such accurate position information can be used to track cows and to record their travel paths and their use of different areas of the barn. In addition, we tested the system's suitability for monitoring and quantifying social interactions. Though displacements of one cow by another seemed to result in characteristic patterns of changes in the relative distance between the two cows, most of the displacements did not follow this pattern closely enough to allow the automatic detection of displacements. By contrast, we show that the proximity between two cows recorded automatically with the positioning measurement system correlated well with the proximity recorded by direct observation of the cows, and provided a more detailed and exact record over the same period of time. There were no indications that wearing the transponder restricted the behaviour of the cows. In conclusion, the results of our evaluation suggest that the radar-based position measurement system is a useful tool for simultaneously recording the positions of all animals in large dairy-cow herds with great accuracy.

Keywords: Dairy cows; Local position measurement; Tracking; Proximity; Displacements

1. Introduction

To assess the behaviour of a cattle herd, it is often necessary to observe the animals in their day-to-day housing conditions. If possible, individual animals should be followed, because a given housing system may influence the behaviour of individuals differently, e.g. low-ranking cows may be more affected in competitive situations (Phillips and Rind, 2002; Harms et al., 2005). With regard to dairy cattle, we are often interested in a detailed recording of the paths and whereabouts of the individual cows, i.e. the time spent in different areas of interest (Galindo and Broom, 2000; Lexer et al., 2004) and in their social interactions (DeVries et al., 2004). Obviously, individuals depend on each other in their social interactions, but may also do so in a more subtle way in their travel paths. Thus, it is often useful

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or even necessary to record the behaviour of all members of a herd simultaneously, which is complicated with large herd sizes.

In previous studies, video recordings or direct observations have been the most common methods for monitoring the behaviour of individuals in dairy-cow herds (DeVries et al., 2004; Lexer et al., 2004). These methods are suitable for studies with small herds (15–20 cows), but are prone to difficulties with larger herds, or with studies involving the observation of several herds. To observe a large cattle herd either directly or by means of video monitoring, a large number of observers, or a huge amount of equipment such as cameras and video recorders are needed to keep the entire herd continuously in view. If video is used, additional manpower is required to score the videos. This is also true if a series of small herds are monitored. The problem of labour input is further amplified if the behaviour to be quantified occurs at a low frequency, e.g. aggressive interactions between specific members of a herd, because many hours of direct observations or scoring videos are spent waiting for the specific situation. Moreover, if the behaviour is to be recorded for 24 h a day, these conventional methods are only applicable with an extra light source for watching the animals at night, which may affect their behaviour (Nicks et al., 1989; Petterson and Wiktorsson, 2004). Finally, it is usually necessary to mark the cows for direct or video observations to make them more easily recognisable; this again requires labour input.

To overcome the difficulties of these conventional methods, an automatic tracking system based on magnetic induction was developed and tested at our research station (Bollhalder and Krötzl Messerli, 1997; Schrader, 2002). This system, however, was still limited for several reasons: first, the antennas had to be built into the floor, which was reflected in high construction costs; second, the network of antenna cables laid out determined the accuracy of the location estimate, which thus needed to be predefined and encompassed larger functional areas (such as the exercise yard); third, the system was not easily transferable to other farms to achieve a broader and thus more valid data sample.

In the study presented here, we further improved cow-behaviour recording technology by using a local positioning measurement system based on radar technology which had been developed for sports (LPM®, http://www.lpm-world.com; Stelzer et al., 2004; Pourvoyeur et al., 2006). Given its technical characteristics, the system should be suitable for continuously monitoring and recording the positions of all cows, even in large dairy herds. As the system's output is coordinates in space which were expected to be very accurate, no predefined areas of activity are necessary. Locations are estimated at a high frequency, and thus even quick movements can potentially be detected. Finally, the system consists of a set of antennas (so-called base stations), glass fibre cables and a computer, and can thus be set-up in different barns.

Below, we present data on the accuracy of the LPM system in locating transponders at fixed positions and in movement tracking. The study was carried out in an open loose-housing barn with an outside yard built for 60 dairy cows. There were two major challenges in applying this system to a dairy loose-housing system: first, some barn equipment is made of metal, which can interfere with signals in the radar frequency; second, cows had to be able to wear a transponder capable of transmitting signals for several days without disturbing their behaviour. Measurements of the accuracy of the system are needed as basic data if the travel path of the cows and the time they spend in different areas of the barn are of interest. Furthermore, the positioning system could also be suitable for recording data on social relationships. It was expected that proximity data, which is likely to reflect various aspects of social interactions (Kummer, 1975; Hemelrijk, 2000), as well as displacement data (Lexer et al., 2004; Petterson and Wiktorsson, 2004) could be recorded with the LPM system because these variables can be collected from the LPM data based on the distances between the locations of two cows and on the relative change in these distances, respectively. In order to evaluate the system's ability to measure social relationships, we compared data of automatically recorded proximity and displacements to those of concurrent direct observations.

2. Materials and methods

2.1. Tracking system

We used a local positioning measurement system LPM® (http://www.lpm-world.com; ABATEC electronics systems, Regau, Austria) which transmits its signal on a radar frequency (5.8 GHz; Stelzer et al., 2004). In principle, the base system with six base stations (antennas) is able to cover an empty field of 500 m × 500 m (car racing, football pitch, speed skating), to track up to 16,000 transponders with a 2D precision of 5 cm on a plane and unstructured surface, and to estimate the position of a set of transponders 300 times/s. Several such 500 m × 500 m cells can be combined.