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Research Paper

A software tool for the automatic and real-time analysis of cow velocity data in free-stall barns: The case study of oestrus detection from Ultra-Wide-Band data

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The increase in the design and utilisation of real-time location systems has produced a huge amount of data to be handled in real time. As a consequence, challenges still exist in improving the analysis process of data streams by designing new tools. In this context, a software tool for automatic and real-time analysis of cow velocity data acquired by an ultra-wide band real-time location system (UWB RTLS) in a free-stall barn was designed and developed. A functionality implemented in this software determined the instant velocity of each cow over time, which was represented through an interactive graph (CowVelocityGraph). Feasibility of the software tools for the visualisation and analysis of UWB data was assessed. A use case of this software tool was carried out to verify its suitability to acquire useful information related to the occurrence of cow's oestrus, which is the case study of this research. The results showed that a pattern, related to the behaviour of the cow analysed, could be identified in CowVelocityGraph when the state of oestrus occurred, allowing for visualisation and analysis of UWB data.

The software developed in this study provides the user with the ability to work in real time by acquiring the RTLS data updated at short time intervals, greatly exploiting the UWB RTLS potentialities. Further tests need to be repeated in different farming conditions, on a significant number of cows. On a broader perspective, this study addressed the lack of analysis tools for data streams acquired in livestock houses.

1. Introduction

In buildings for intensive livestock farming, a large number of animals are raised in highly controlled environmental conditions. In this context, the development of automated monitoring systems has enhanced animal housing by introducing technological innovations capable of improving animal welfare and, therefore, guarantee a improved food safety for consumers (Tullo, Fontana, & Guarino, 2013).

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Different real-time monitoring systems for animal localisation and the detection of cow behavioural activities have been tested, such as wireless network-based systems (Huhtala, Suhonen, Mäkelä, Hakojärvi, & Ahokas, 2007; Kumar & Hancke, 2015; Tullo, Fontana, Gottardo, Sloth, & Guarino, 2016; Wietrzyk & Radenkovic, 2008), Bluetooth technology-based systems (Tøgersen, Skjøth, Munksgaard, & Højsgaard, 2010), radar technology (Gygax, Neisen, & Bollhalder, 2007), UHF technology-based systems (Ipema, Van De Ven, & Hogewerf, 2013; Porto et al., 2012), real-time pedometers (Brehme, Stollberg, Holz, & Schleusener, 2008; Chanvallon et al., 2014; Jónsson, Blanke, Poulsen, Caponetti, & Højsgaard, 2011), accelerometers (Arcidiacono, Porto, Mancino, & Cascone, 2017a, 2017b; Maselyne et al., 2017; Nielsen, Pedersen, Herskin, & Munksgaard, 2010; Oudshoorn et al., 2013; Pastell, Tiusanen, Hakojärvi, & Hänninen, 2009), and motion and image analysis-based methods (Porto, Arcidiacono, Anguzza, & Cascone, 2015; Tsai & Huang, 2014; Van Hertem et al., 2014; Van Hertem et al., 2016; Viazzi et al., 2014). As a consequence of the use of these systems, a huge amount of data has to be handled, also in real time. Therefore, challenges still exist with data analysis and interpretation.

It is recognised that there is a need both to improve the analysis process of data streams and to design new tools for analysis and pattern identification, management analysis, indexing, querying and visualisation of information (Gao, Campbell, Bidder, & Hunter, 2013). These new tools could support farmers in herd management and researchers in analysing animal behaviour by using real-time monitoring systems and information-based technologies.

With regard to intensive dairy cow farming, efficient data management is the key to improve breeding, e.g., to control cow's oestrus and reduce calving intervals, to carry out early detection of diseases, and to verify welfare status of cows.

In previous research studies (Porto, Arcidiacono, Anguzza, Giummarra, & Cascone, 2013; Porto, Arcidiacono, Giummarra, Anguzza, & Cascone, 2014), the localisation and identification performance of a real-time location system (RTLS) based on Ultra Wide Band (UWB) technology (Ubisense, UK) within a free-stall barn were evaluated. Localisation and identification performance of the RTLS was assessed by applying an outlier data cleaning technique to tag localisation errors and using precision and sensitivity indices. The results showed that, in the environmental conditions of the barn, the RTLS produced errors which were comparable to those declared by the RTLS producer for the fixed reference tag whereas localisation errors relating to tags applied to the body of the cows were higher, yet less than 1 m. RTLS performance in this environment proved to be generally independent of cow behaviour, as has been observed for other systems, indicating that RTLS should be suitable to determine the occupancy level of the different functional areas of the barn, compute cow behavioural indices, and track each animal in the herd. Possible applications of this UWB-based RTLS were indicated, such as real-time data analysis aimed at the early detection of a specific physiological status (e.g., cow's oestrus) or disease (e.g., lameness).

In the Ubisense UWB system, data management tools for the analysis of real-time data were very limited and unsuitable to analyse the data acquired by the system in the specific environment of dairy houses. Therefore, specific data analysis tools need to be designed and implemented, and the suitability of data to be utilised for early detection of a specific status of the cow should be assessed.

On this basis, the main objective of this study was to contribute to filling the gap of the lack of visualisation and analysis tools for data streams coming from a Ubisense UWB system. A software tool (CowVelocityGraph) was developed for the automatic and real-time analysis of cow location and velocity data, which were obtained from an Ubisense UWB system installed in a free-stall barn. A specific use case of this software tool was designed and then implemented to acquire and obtain useful information relating to the occurrence of cow's oestrus, which is the case study of this research. Other specific use cases could be performed for other purposes (e.g., diseases and behavioural activities). The collection of oestrus data in real time is of considerable importance to avoid delayed cow inseminations, which could reduce cow fertilisation rate, increase calving intervals, decrease milk production, and, as a consequence, have negative economic impacts on farm budget and costs.

2. Materials and methods

The experiment was performed in a dairy house, located in the province of Ragusa (Sicily, Italy), which had a rectangular plan with three sides completely open. The area of interest was composed of the resting area with 16 head-to-head cubicles, the feeding alley, the service alley, and two side passages (Fig. 1).

The commercial RTLS based on UWB technology (Ubisense, UK) was installed in the selected area of the barn to detect the position of eight dairy cows. The RTLS was composed of four sensors IP30 Series 7000 and eight Compact Tags IP65. The system was wired and connected to a Power-over-Ethernet (PoE) switch, which in turn was connected to a personal computer. The four sensors were fixed at the corner pillars of the area of interest, at a height of 3.78 m above the floor. The RTLS acquired information on the position of the eight cows at 1-second intervals. Please refer to our previous work (Porto et al., 2014) for further details on the configuration of the RTLS and its localisation and identification performance when installed in a free-stall barn.

In this paper, a specific software was developed by using Microsoft® Visual C# Express (framework.NET) to allow visualisation of cow velocity data acquired by the UWB RTLS. In Fig. 2 the flow-chart of the algorithm implemented in this software is shown.

2.1. Data selection

As described in our previous work (Porto et al., 2014), a database was populated in the acquisition phase of the data produced by the UWB-based RTLS. The software proposed in that paper was designed to access the database and extract the information required for the analysis. When performing data elaboration, the user had the possibility to filter data by a SQL query, which worked on the data table containing all the

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