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A computer program for monitoring and controlling ultrasonic anemometers for aerodynamic measurements in animal buildings

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ABSTRACT

Ultrasonic anemometers (USAs) are widely implemented in animal housing to measure the air velocity in different measuring points throughout the whole barn, which ultimately leads to determine the velocity fields and the air flow patterns drawing a clear vision of aerodynamics inside animal buildings. The problem is the timely inconsistent data transmission from the different USAs leading to varied data recording, which makes the comparison between the recorded velocities in different points timely inappropriate. One key issue is to monitor and control the USAs, meanwhile, debug and record the data. Therefore, LabVIEW 8.5, which is a platform and development environment for a visual programming language, was used to configure a computer program to monitor and control the USAs. The principal functions of the system are represented in a main block diagram which consists of 39 sub-diagrams. Five versions of the program were consecutively developed, and then each version was validated and further developed to get the next enhanced version, and so on till Version 5.0. The evaluation and data recording are carried out simultaneously, where the data are transferred from the USAs to the program which detects accidental errors that may have been introduced during data transmission or storage using a checksum algorithm. The developed computer program has been implemented successfully for monitoring and controlling USAs used for carrying out air velocity measurements in livestock housing. Three measurements campaigns were performed to investigate the air profile inside a dairy barn under two conditions, which are “ceiling fans on” and “ceiling fans off”, where the average air velocities were 0.98 and 0.59 m s^{-1}, respectively.

1. Introduction

Odors and gases emitted from animal houses are strongly related to airflows (Morsing et al., 2008). Sun et al. (2002) developed computational fluid dynamics (CFD) models to simulate air velocity and ammonia distribution within a hog building. Snell et al. (2003) stated that ventilation rate could be explained by the climatic values (wind velocity, wind direction, temperature, and relative air humidity), where the wind velocity is of central importance for the ventilation. Bartzanas et al. (2007) stated that air velocity measurements incarnate the corner stone for airflow analysis in rural buildings. Bjerg and Sørensen (2008) carried out numerical analysis and mentioned that to fulfil modern demands of airflow in livestock buildings, several procedures – which requires air velocity measurements – should be implemented, and they are: determining air velocity at animal level, limiting air velocity in the animal occupied zone, homogenizing air velocity distribution in the entire barn, determining whether air velocity distribution inside and close to the inlet is similar, investigating air velocity profiles and turbulences, homogenizing air velocity direction throughout the entire barn, reducing air velocity at floor level at high ventilation rate without increasing the pressure drop over the inlet.

Anemometers are sensors which are used to measure wind speed, direction and other characteristics of the flow. There exist different methods. If mechanical cup anemometers are used, the dirtiness of the atmosphere requires an increased frequency of maintenance and close attention to bearings and corrosion. Further, may increase the problem of cup over-speeding and too much shelter may cause anemometers to operate near or below their threshold minimum speed. This must be addressed through the choice of fast-response anemometers, propeller-type anemometers

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or ultrasonic anemometers (USAs). Propeller anemometers are less prone to over-speeding (Oke, 2004). Ultrasonic anemometers can take measurements with very fine temporal resolution, 20 Hz or better, which makes them well suited for turbulence measurements. The lack of moving parts makes them appropriate for long term use and practically maintenance free. One disadvantage can be a lower accuracy due to precipitation (VDI 3786, 1994).

An ultrasonic anemometer measures the times taken for an ultrasonic pulse of sound to travel from an upper transducer to the opposite lower transducer, and compares it with the time for a pulse to travel from lower to upper transducer. Likewise times are compared between each of the other upper and lower transducers. The speed of sound in air can be calculated from the times of flight. In other words, the air velocity along the axis between each pair of transducers can be calculated from the times of flight on each axis. This calculation is independent on factors such as temperature. From the three axis velocities, the air speed is calculated, either as signed *u*, *v*, and *w*, or as Polar and *w* (Gill Instruments Limited, 2009). Generally, the USAs are commonly used to investigate the air velocities, airflows and air profiles in livestock buildings (Quinn et al., 2001; Bartzanas et al., 2007; Teye and Hautala, 2007; Von Bobrutzki et al., 2010, 2011; Fiedler and Müller, 2011; Samer et al., 2011a,b).

When implementing several USAs in animal housing to measure the air velocity in different measuring points throughout the whole barn, the data transferred from the different anemometers are timely inconsistent which leads to varied recording of data making the comparison between the recorded velocities in different point timely inapt. Lacroix et al. (1998) stated that in order to accelerate analyzes and improve decision-making, it is necessary to develop computer tools that have the ability to pre-process the data so as to produce value-added information.

The aforementioned literatures showed that the air velocity profiles and the airflow investigations were carried out either in scale models or using simulation models. Therefore, it is required to carry out similar investigations in practice barns which require controlling and monitoring the anemometers. The objective of this study is to develop a tool to monitor and control the ultrasonic anemometers for aerodynamic measurements in animal barns, and then to debug and timely record the measured values. This paper provides a unified tool for scientists allowing comparison among the results of the different measurements and retracing the data.

2. Materials and methods

2.1. General procedures

The overall computer program architecture consists of user interface, algorithm, display module, and user model; whereas: (a) the user interface has three responsibilities: querying the user for suitable inputs to the algorithm, acquiring knowledge about the individual user to inform the user model, and presenting output to the user, (b) the algorithm carries out an analysis of the user's commands and generates a table of numeric values as output, (c) the display module shows the output of the algorithm and generates displays, taking into account information in the user model, (d) the user model determines general and specific attributes of the user and provides modification rules to the display module, which are used to individualize the display.

The systematic procedures carried out by the program in coordination with the commands given by the user through the user interface, are summarized as following: (a) the data file, where the measured values will be written, and the anemometer(s) that should be used will be called up; (b) the data file and the used anemometer(s) will be called up; (c) the system will attempt to debug all buffers of the implemented anemometer(s); (d) the telegram(s) of the used anemometer(s) will be read continuously, and can be written into the data file if required; (e) all interfaces will be closed; (f) the system will look for errors; and (g) in case of finding errors, they will be displayed.

2.2. Knowledge acquisition

The knowledge used to configure the computer program was acquired from different sources, such as: references, manuals, and experts. The most important manuals were: user manual of USA (Gill Instruments Limited, 2009), universal board user's manual (Moxa Inc., 2008), and LabVIEW user guide. Furthermore, contacts were made with experts to acquire knowledge concerning the required abilities of the program, practical application, and the method of carrying out aerodynamic measurements in animal housing. Further experts were inquired about the algorithm developed for calculating the air velocity by means of *u* and *v* which represent the air velocity components.

2.3. Programming

LabVIEW short for Laboratory Virtual Instrumentation Engineering Workbench (LabVIEW Professional Development System 2007, Version 8.5, National Instruments Corporation, Austin, TX, USA), which is a platform and development environment for a visual programming language, was used to configure the computer program via the algorithms in order to form the block diagram of the software system, and then to develop the user interface. The algorithms, rules, and functions are included in the detailed block diagrams with descriptive characteristics at each branch code and a decision at each terminal node.

The computer program was prototyped to contain one main block diagram which consists of 39 detailed block sub-diagrams for monitoring and controlling ultrasonic anemometers during aerodynamic measurements in animal barns and then debugging and recording the data, i.e. the measured values, transmitted from the anemometers into a Text Document which represents the data file. Figs. 1 and 2 show the overview block diagram of the developed software and the reciprocal interactions between the different main functions. The block diagram is the system's back diagram code which represents the functions by blocks connected by lines showing the relationships between the blocks. Hence, this block diagram is a visual description of the course of actions carried out by the software system.

2.4. Data transmission

The specified baud rate for data transmission from the different ultrasonic anemometers to the program is 19200 symbols (ASCII Code) per second. The data are transferred from the ultrasonic anemometer to the program according to the following mode or telegram: identification node address (anemometer name), *u* axis speed and polarity (m s^{-1}), *v* axis speed and polarity (m s^{-1}), *w* axis speed and polarity (m s^{-1}), units (metric system), sonic temperature (*T*, °C), status or error code, analogue inputs (A. I/P) and checksum (Fig. 3).

2.5. Validation and evaluation

The validation of a computer program aims to determine if the system is operating correctly or not. Therefore, five versions of the program had been consecutively developed, where each version was validated to uproot system errors, then the amendments and the corrections were executed getting a new version which in turn