Computers and Electronics in Agriculture 142 (2017) 424–428

Contents lists available at ScienceDirect

Computers and Electronics in Agriculture

journal homepage: www.elsevier.com/locate/compag

Application note

Application note: Labelling, a methodology to develop reliable algorithm in PLF

Emanuela Tullo[a,1], Ilaria Fontana[a,1,*], Alessia Diana[b,c], Tomas Norton[d], Daniel Berckmans[d], Marcella Guarino[a]

[a] Department of Environmental Science and Policy, Università degli Studi di Milano, Via Celoria 10, 20133 Milano, Italy
[b] Pig Development Department, Teagasc, Moorepark, P61 0996 Fermoy, Co. Cork, Ireland
[c] School of Veterinary Medicine, UCD, Belfield, D04 V1W8 Dublin 4, Ireland
[d] Department of Biosystems, Division Animal and Human Health Engineering, M3-BIORES, Katholieke Universiteit Leuven, Kasteelpark Arenberg 30, 3001 Leuven, Belgium

ARTICLE INFO

Keywords:
Labelling
Sound
Image
Algorithm
Precision Livestock Farming

ABSTRACT

Automatic animal monitoring through Precision Livestock Farming (PLF) tools is a method to support farmers in achieving farm sustainability. The development of PLF systems requires close interdisciplinary collaboration between sector experts, farmers, animal scientists and bio-engineers. Labelling is a key activity in the development of reliable algorithm to be included in PLF tools. It is a set of procedures that animal experts must embark to precisely define and interpret detailed variations in measured field signals. This application note will describe the fundamental aspects of sound and image labelling and how this has enabled the engineering of useful automated PLF systems.

1. Introduction

Precision Livestock Farming (PLF) tools aim to be fully automated, continuous management systems that give credible information and alarms based on continuous monitoring of animals. PLF is defined as: "the application of process engineering principles and techniques to livestock farming to automatically monitor, model and manage animal production" (De Montis et al., 2017; Wathes, 2010). Indeed, PLF tools convert in real-time animal behaviour and responses captured with microphones, cameras and sensors into relevant information that enables on-line automated control and monitoring systems. Indeed, the PLF approach can be easily applied to different management aspects, focusing both on the environment and on the animals, from the individual to the entire flock/herd (Wathes, 2010), managing feeding strategies, controlling growth rate and, monitoring animal activity (Fontana et al., 2015; Peña Fernández et al., 2015). PLF consists of non-invasive automated technologies providing early warning for the identification of animal production, health and welfare problems on farms (Guarino et al., 2017). The prompt reaction to any change in health, welfare and productive status is the key for the reduction in drugs usage and for the improvement of animal wellbeing. (Berckmans et al., 2015). Developing automated monitoring systems requires data collected through environmental, remote and wearable animal-based sensors. The design and implementation of technologies using sounds and images are hugely interesting since animals are not handled. Moreover, animals communicate especially through auditory and visual signals, hence important bio-responses are often behavioural ones (Houpt, 2011). Indeed, stakeholders often carry out audio-visual scoring based either on their experience or on science-based protocols to assess animal health and welfare (Welfare Quality, 2009). Due to time and cost constraints, the duration and frequency of on-farm visits are generally limited and, therefore such circumstances do not guarantee a proper assessment of all animals. Compared to manual scoring, PLF also gives an objective and quantitative continuous measure for several aspects of animal behaviour. As a result, PLF technologies are becoming more relevant tools, supporting farmers and veterinarians in their decision making process.

2. Labelling

Animal bio-responses must be identified to develop reliable PLF monitoring systems. Professional figures such as veterinarians and animal scientists define Gold Standard (reference system) those variables by which animals' bio responses are evaluated. Gold Standard

* Corresponding author.
E-mail address: ilaria.fontana@unimi.it (I. Fontana).
[1] These authors have contributed equally to the present work.

http://dx.doi.org/10.1016/j.compag.2017.09.030
Received 4 July 2017; Received in revised form 20 September 2017; Accepted 21 September 2017
Available online 29 September 2017

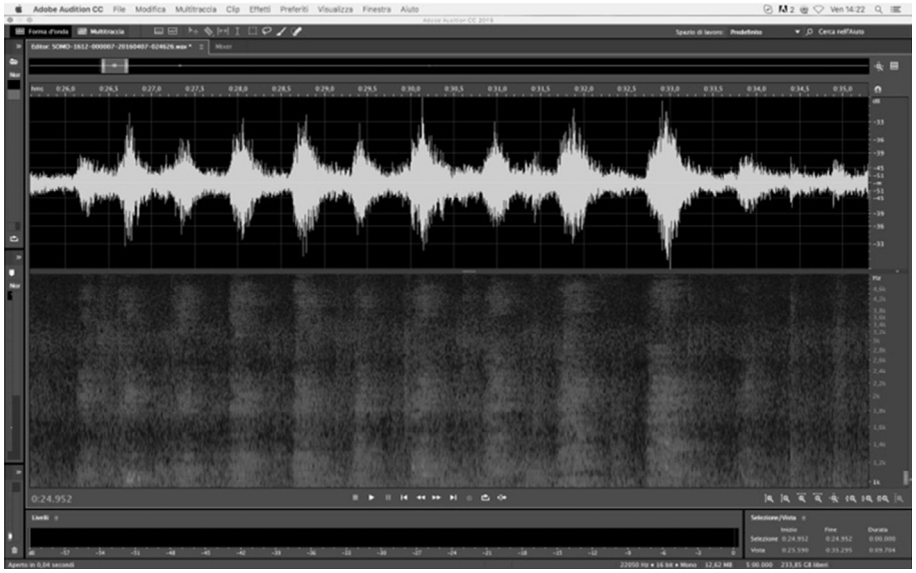

Fig. 1. Screenshot of Adobe® Audition™ CS6. Waveform (upper part) and spectral display (lower part) of an audio file.

investigations produce a reference for health and welfare status but are known to be expensive and difficult to conduct in commercial settings.

These bio-responses give the indication of sounds, images and parameters that can be used to develop algorithms which are capable to predict and manage animal health, welfare and production, allowing farmers to promptly take actions (climate control, feeding strategies, etc.) in order to solve issues detected at the farm. An algorithm is a step-by-step procedure for doing calculations and is used for data processing and automated reasoning. The specific character of algorithms used in biological processes is that most of them are real-time algorithms since that living organisms are time-varying and individually different. The developed algorithm calculate the relation between bio-signals and "feature variables" in real time and fully automatically, allowing an automatic monitoring of animal bio responses. The idea of real time monitoring assumes a simple way to measure a variable that can give an early warning for the farmer. This simple variable is called "feature variable"; for example, the feature variable to detect respiratory infection is the number of coughs (Berckmans, 2013). Fundamental for the development of an algorithm for cough counting is to identify when exactly a cough is starting and when it is ending rather than the real number of coughs. This is done through a careful analysis of field data in an audio-visual way with a specific methodology: counting and marking coughs (1) directly at the farm; (2) off-line through an audio-visual marking procedure on the measured data. This activity is called *labelling*; it is the detailed manual audio-visual analysis of the feature variables from collected data to be used as a reference for algorithm development (Tullo et al., 2013). This is less expensive and easier but accurate as much as the observation performed at farm level. People performing labelling procedure are defined "labellers" who are trained experts that can identify sounds, images and parameters relevant for the development of animal-based algorithms. Labelling is essential to translate the knowledge of animal experts into smart algorithms. It is a unique expertise, core of the PLF tool development that combines animal science with signal interpretation, through a strong inter-disciplinary collaboration between scientists, farmers, veterinarians and algorithm engineers.

Labelling involves the identification of beginning, ending and duration of events in sounds, images and/or sensor data that indicate animal status. Thus, data (e.g. sounds or images) are carefully labelled and then engineering teams create an algorithm based on such database. Furthermore, an accurate labelling procedure is the basis for the development and subsequent validation of reliable algorithms (Porto et al., 2014). In general, the procedure for the algorithm validation consists in comparing data automatically obtained from automated systems with those obtained by manual labelling procedure. During the validation process the events classified by labellers are considered the Gold Standard and defined as true positive, while events wrongly classified by automated systems are considered as false positives (Arcidiacono et al., 2017). Such parameters are necessary to evaluate the accuracy, specificity and the sensitivity of the algorithm (Nasirahmadi et al., 2017).

2.1. Sound labelling

Sound labelling involves the observation, extraction, identification and classification of individual animal sounds based on the amplitude or frequency of the sound signal in audio files recorded at farm level referring to key indicators and Gold Standard. Auditory recognition of sounds coming from a noisy environment such as the farm is challenging. On farms, feeding systems, gates, environmental enrichments and animal activity may overlap sounds and vocalisations; furthermore, acoustic sources may be far from microphones because animals are moving. Acoustic features of farm buildings may alter sound propagation due to echoes and reverberations. Due to their discontinuity, it is quite arduous to filter out all these background noises; therefore, audio identification depends on the subjectivity of labellers and their accuracy in the interpretation/understanding of sounds. For this reason it is helpful to support listening with visual information about the energy envelope of sounds recorded. Audio editing software such as Adobe® Audition™ CS6 provide visual representation of sound waves. The waveforms displayed are used to evaluate audio amplitude or the spectrum of the sound, which reveals audio frequency (Fig. 1), allowing easily audio editing operations and labelling. During the listening, it is possible to zoom in and out in the two domains to visualize the energy envelope of each sound. When a sound of interest (e.g. a cough, sneeze or vocalisation) is detected, the labeller can mark it and insert a label describing the sound. For each sound, the start, the end point and the duration are automatically recorded.

2.2. Video labelling

Video labelling is the accurate detection of the occurrence of behaviours performed by animals. It consists in the manual extraction and classification of individual frames on a recorded video referring to key indicators and Gold Standard. Sometimes, the duration of behaviours may be very short, and the video labelling procedure can be