Disponible en ligne sur
ScienceDirect
www.sciencedirect.com

Elsevier Masson France
EM|consulte
www.em-consulte.com

IRBM

IRBM 35 (2014) 173–181

Original article

Non-invasive devices and methods for large animal monitoring using automated video processing

F. Porée [a,b,*], V. Creuze [c], M.-L. Specq [d], N. Samson [d], J.-P. Praud [d], G. Carrault [a,b]

[a] *Laboratoire Traitement du Signal et de l'Image (LTSI), Université de Rennes 1, Campus de Beaulieu, 35042 Rennes cedex, France*
[b] *Inserm, U1099, Université de Rennes 1, Campus de Beaulieu, 35042 Rennes cedex, France*
[c] *LIRMM, Université de Montpellier 2, CNRS, 161, rue Ada, 34095 Montpellier cedex 5, France*
[d] *Departments of Pediatrics and Physiology, Université de Sherbrooke, 3001 12th North Avenue, Sherbrooke (QC), Canada*

Received 9 October 2013; received in revised form 20 January 2014; accepted 5 February 2014
Available online 1 May 2014

Abstract

Objectives. – It is now standard for polysomnographical equipment to include video recording, although this modality is generally underexploited, since there is no automated processing associated with the latter. In the present report, we investigated the set of features that can be automatically extracted from a video recording, in the context of monitoring of freely moving, non-sedated, newborn lambs.
Material and methods. – Our database contained seven lambs and a total of 11 recordings, using two different cameras allowing a top view and a side view. Using appropriate methodologies, we show that it is possible to estimate the lamb's movements, its posture (standing or lying) as well as its covered trajectory.
Results. – Results are discussed as a function of the camera and show that side view recording is well suited for accurate scoring of the lamb's posture, whereas trajectory is best estimated using the top view camera. On the other hand, both cameras provide qualitatively similar results for the estimation of movement of the animals.
Conclusion. – The data gained from automated video processing, as reported herein, may have multiple applications, especially for animal studies, but may also be extended to human sleep monitoring.

1. Introduction

Better understanding and treatment of disorders of cardiorespiratory control in newborns and infants still offer many challenges. The latter include prevention and treatment of frequent disorders such as apneas of prematurity [1] and apparent life-threatening events in infants [2], as well as prevention of sudden infant death syndrome [3]. Given the limitation of research protocols feasible in human infants, an important part of our research program focuses on the study of various newborn lamb models, mimicking conditions we encounter daily in human infants [4,5]. Most of our lamb studies necessitate prolonged monitoring for hours throughout the various states of consciousness, which can be repeated along several days. We systematically use a custom-made radiotelemetry system for polysomnography (PSG) recording, which allows the monitoring of an extensive number of electrophysiological signals 24 hours a day [6].

The wealth of data collected during such prolonged PSG first led us to search for a simple means to recognize the standing posture in lambs, in order to ascribe wakefulness to these time epochs. In addition, the recent need to further assess movement activity, as well as tracking locomotor activity, led us to review the available options for studying movements. Changes in body position from lying to standing posture in the lamb have previously been recorded by a pressure catheter attached to the back of the animal or inserted intravasculary, meaning that the lamb is tethered to a pressure gauge [7]. While actimetry has been successfully used to quantify movement activity over several days in lambs, it is however unable to track locomotor activity [8]. To our knowledge, available photobeam chambers, e.g. from San Diego Instruments, San Diego, CA, USA or Med Associates, Inc., St. Albans, VT, USA, can monitor locomotor activity in rodents only [9]. Force and pressure plates can track locomotor activity in large animals, however these sophisticated techniques

* Corresponding author. Laboratoire Traitement du Signal et de l'Image (LTSI), Université de Rennes 1, Campus de Beaulieu, 35042 Rennes cedex, France.
E-mail address: fabienne.poree@univ-rennes1.fr (F. Porée).

1959-0318/$ – see front matter © 2014 Elsevier Masson SAS. All rights reserved.
http://dx.doi.org/10.1016/j.irbm.2014.02.002

are better suited for fine analysis of gait kinetics [10]. Finally, thermic camera recordings have been used to acquire trajectory in rats.

From the early days of physiology, direct visual observation has been an important component of experimental methods to document a subject's behavior. Over time, interpretation of recordings of multiple physiological signals, such as PSG, has largely benefited from the association of behavioral criteria and electrophysiological criteria for sleep staging. Technical advances have allowed the development of various video-monitoring systems with working capabilities under both daylight as well as infrared illumination. As recommended by current guidelines (e.g. ASTA/ASA Addendum to AASM Guidelines for Recording and Scoring Sleep; Paediatric Rules, 2011), it is now standard for PSG equipment to include video recording, in order to visually document movements and posture during sleep in humans. Review of the literature reveals a high number of studies dealing with the use of visual analysis of video monitoring for sleep staging in humans [11–13], and animals [14,15] or for studying movements during sleep in children with hyperactivity disorder [16]. Finally, more recent works highlight the potential of automated video processing for movement and posture detection in the context of sleep disorders [17–19], epilepsy [20–23] or activity detection [24–26]. As a result, video recording thus appeared as a simple, inexpensive and non-invasive approach seemingly capable of fulfilling several research needs.

Video-monitoring systems, such as Ethovision XT7 (Noldus, Wageningen, The Netherlands), ANY-maze (Wood Dale, IL, USA) or Stereoscan (Clever Sys, Reston, VA, USA) are also used for the automated tracking and analysis of movement, activity, and behavior of any animal types, including from drosophila and zebrafish to farm animals in all forms of enclosures [27–33]. Such systems can be used to calculate movement velocity and distance travelled as well as to record the trajectory of a moving animal under various conditions [34–36]. They are however fairly complex and do not allow to recognize standing from lying postures.

The present work proposes a system including the devices and the methods allowing to extract a set of parameters and informations on the activity and behavior of non-sedated, freely moving lambs, using video monitoring. For this purpose, three methods were developed in order to: (1) estimate movement, (2) differentiate between standing and lying postures, and (3) characterize locomotor activity of a freely moving animal in an enclosure. Two infrared cameras were used and, based on literature review, different video processing methods were implemented in order to assess the contribution of top and side views individually as well as in combination. These methods present a real advantage since they were adapted to work automatically for any protocol and animal. They also present substantial time savings considering that such experiments are often time consuming and require extensive experience. In addition, while this study shows the application to monitoring of lambs, it can be applied to other types of animals.

This paper is organized as follows. Devices and methods are detailed in Section 2. Section 3 outlines the protocol, the database and the results. A discussion upon the methods and the results is driven in Section 4. Finally, Section 5 gives the conclusion and discusses several real-life context applications in order to underline the interest of the approach.

2. Device and methods

The full system that we developed includes the device and the video analysis methods. They are described hereafter.

2.1. Device

In order to obtain a good view of the animal, the device was composed as follows:

- the studied lamb was housed in a Plexiglas chamber, with a surface of 1.3 m^2, where it could move freely and have access to food and drink;
- since experiments took place during night or in obscurity, the enclosure was illuminated by an infrared lamp (IR);
- two infrared-sensitive video cameras were installed to record the scene. One was located above the chamber, looking downwards (top view of the scene), and the other facing the chamber, thus giving a side view of the scene;
- the lamb was equipped with a tag, a black square with sides of 5 cm, affixed on the back, to follow the animal in the top view case. The size of the marker has been chosen according to the following two constraints. Not only it has to be maximized in order to ease its detection (especially when it is tilted) in spite of the bad imaging conditions (low resolution webcam with poor lighting conditions), but it also has to fit in the limited available area on the scientific instrumentation bag fastened onto the back of the lamb (Fig. 9). The lamb had also been surgically instrumented with several electrodes and sensors to collect physiological signals for another study, which is out of the scope of the present article.

2.2. Video analysis methods

After the recordings of videos of the animal, different types of information may be extracted in order to obtain a global and detailed interpretation of its behavior, for long durations. For this purpose, we propose to estimate three features of the animal's behavior:

- the movement which quantifies the amount of activity during the experiment;
- the posture which completes the precedent and provides information on alternation of sleep/wake stages (since an animal does not sleep while standing in general);
- the locomotor activity which allows to characterize all the parameters related to the activity of the animal (such as explored surface, covered distance, etc.).

Depending on the features, either top view, side view or both cameras may be used.