BIOSYSTEMS ENGINEERING 141 (2016) 19–30

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/issn/15375110

Research Paper

Monitoring pig movement at the slaughterhouse using optical flow and modified angular histograms

Ruta Gronskyte [a,*], Line Harder Clemmensen [a], Marchen Sonja Hviid [b], Murat Kulahci [a,c]

[a] DTU Compute, Technical University of Denmark, Kgs. Lyngby, Denmark
[b] Danish Meat Research Institute, Taastrup, Denmark
[c] Department of Business Administration, Technology and Social Sciences, Luleå University of Technology, Luleå, Sweden

ARTICLE INFO

Article history:
Received 18 March 2015
Received in revised form 16 August 2015
Accepted 5 October 2015
Published online 10 December 2015

Keywords:
Optical flow
Support Vector Machines
Modified angular histograms
Abnormal movement detection

We analyse the movement of pig herds through video recordings at a slaughterhouse by using statistical analysis of optical flow (OF) patterns. Unlike the previous attempts to analyse pig movement, no markers, trackers nor identification of individual pigs are needed. Our method handles the analysis of unconstrained areas where pigs are constantly entering and leaving. The goal is to improve animal welfare by real-time prediction of abnormal behaviour through proper interventions. The aim of this study is to identify any stationary pig, which can be an indicator of an injury or an obstacle. In this study, we use the OF vectors to describe points of movement on all pigs and thereby analyse the herd movement. Subsequently, the OF vectors are used to identify abnormal movements of individual pigs. The OF vectors, obtained from the pigs, point in multiple directions rather than in one movement direction. To accommodate the multiple directions of the OF vectors, we propose to quantify OF using a summation of the vectors into bins according to their angles, which we call modified angular histograms. Sequential feature selection is used to select angle ranges, which identify pigs that are moving abnormally in the herd. The vector lengths from the selected angle ranges are compared to the corresponding median, 25th and 75th percentiles from a training set, which contains only normally moving pigs. We show that the method is capable of locating stationary pigs in the recordings regardless of the number of pigs in the frame.

1. Introduction

Today many consumers are increasingly interested in the welfare of the animals used for commercial meat production. Animal behaviour during the production process can be used to evaluate animal welfare (Brandt, Rousing, Herskin, & Aaslyng, 2013). However, constant monitoring of animals by humans in industrial farms is nearly impossible. Such constraint has created great interest in automated livestock

* Corresponding author. Tel.: +45 45 25 53 51.
E-mail address: rgro@dtu.dk (R. Gronskyte).
http://dx.doi.org/10.1016/j.biosystemseng.2015.10.002

monitoring. There have been several attempts to identify (Tu, Karstoft, Pedersen, & Jørgensen, 2013; Guo, Zhu, Jiao, Ma, & Yang, 2015) and track pigs (Oczaka et al., 2014; McFarlane & Schofield, 1995; Kashiha et al., 2013a; Lind, Vinther, Hemmingsen, & Hansen, 2005; Ahrendt, Gregersen, & Karstoft, 2011) as well as chickens (Dawkins, Cain, & Roberts, 2012; Kashiha, Pluk, Bahr, Vranken, & Berckmans, 2013b; Nakarmi, Tang, & Xin, 2014), and cows (Huhtala, Suhonen, Mäkelä, Hakojärvi, & Ahokas, 2007; Porto, Arcidiacono, Anguzza, & Cascone, 2015) in farms. Different movement and density measures have proved useful in ensuring animal welfare (Rushen, Chapinal, & Passill, 2012; Dawkins et al., 2012; Kashiha et al., 2013b; Youssef, Exadaktylos, & Berckmans, 2015; Nakarmi et al., 2014; Porto et al., 2015). The animals can be tracked either by using radio tags attached for example to the animal's ear (Ng, Leong, Hall, & Cole, 2005; Tøgersen, Skjøth, Munksgaard, & Højsgaard, 2010; Ruiz-Garcia & Lunadei, 2011; Porto, Arcidiacono, Giummarra, Anguzza, & Cascone, 2014), passive transponders injected into the animal's body (Prola, Perona, Tursi, & Mussa, 2010; Caja et al., 2005) or by video surveillance. A computer vision approach is non-intrusive and can be adapted to different animals. The cases mentioned above, which all employ computer vision, monitor animals in farms where all areas of interest can be covered with one or a few cameras. When the videos are recorded in constrained areas, which the animals cannot leave, additional markers (Kashiha et al., 2013a) or features (Ahrendt et al., 2011) can be used to track the animals' movement. Ahrendt et al. (2011) propose a method to track individual pigs and can follow three pigs in a constrained area over an 8-min period without losing track. However, monitoring pigs in slaughterhouses creates additional challenges: (1) large numbers of animals, which are very similar to each other, are often present in small areas, and (2) even multiple cameras cannot cover all of the process line, thus animals can leave and come back into a monitored area. The disadvantage of using the marking technique proposed by Kashiha et al. (2013a), which consists of stamping a specific pattern on the back of the pigs, is that additional people would be needed as well as it being time-consuming to uniquely mark 12,400 (Danish Crown, 2014) pigs per day. Tracking individual features as proposed by Ahrendt et al. (2011) or using tags as proposed by Ng et al. (2005), Prola et al. (2010) and Caja et al. (2005) would be too computationally expensive for a real-time monitoring system. These disadvantages can be overcome by using our proposed technique and by analysing all pigs as a herd with the caveat that the ability to track an individual pig is lost.

In dense crowd surveillance of humans, it is rarely attempted to identify the individual subjects. In most of these cases, optical flow (OF) is used (Helbing, Johansson, & Al-Abideen, 2007; Andrade, Blunsden, & Fisher, 2006; Ali & Shah, 2008). OF is a pattern that represents relative motion between two consecutive frames in a video and is presented as a vector field of motion over the entire frame (Wedel & Cremers, 2011). Each OF vector indicates the direction and the distance of movement of a single pixel. OF estimation is a non-intrusive and computationally cheap method. A standard consumer camera is sufficient to record the movement and can be mounted such that it does not interfere with the usual routine of the subjects. This paper describes a case study for monitoring the welfare of pigs while unloading from trucks at a slaughterhouse that can handle up to 62,000 (Danish Crown, 2014) pigs per week. The majority of pigs in our recordings are crossbreeds between Duroc, Danish Landrace and Yorkshire (Dx(LxY)). Pure Duroc is typically red in colour. Thus, some crossbred pigs are coloured. Our recordings mainly contain pigs that are white with only a few coloured pigs. The colour similarities make the separation of the nearby pigs computationally expensive. The similarities in the body size also make it challenging to track individual pigs. Pigs weighed 100–110 kg and were approximately 6 months of age.

To the best of our knowledge, only a few attempts have been made in the literature to monitor livestock using OF (Dawkins et al., 2012; Dawkins, Lee, Waitt, & Roberts, 2009). To quantify the behaviour of an individual animal, Dawkins et al. (2012) used low-level statistics such as the mean, variance, skewness and kurtosis of the OF vectors of chickens and found a strong correlation between statistics and the Bristol Gait Score, which assesses leg weakness. In this paper, we show that the low-level statistics used by Dawkins et al. (2012) are not optimal when the animals are recorded in proximity and have a specific walking pattern such as trot. In addition, low-level statistics are not suitable for monitoring large numbers of pigs as they average out the few pigs that are moving abnormally. We refer to a specific walking pattern (trot) as “local movement”. We define “global movement” of an animal as the overall speed and direction of the animal. OF vectors of monitored pigs show not only the global movement but also the local movement of the animals. Low-level statistics of the OF vectors do not represent the global movement of the animals when a strong local movement, i.e. trot, is present. In this paper, we propose to use modified angular histograms (MAH), which summarise the OF vector lengths within the corresponding angle range. By using MAH, we can filter the local movement out of the OF vectors, leaving only the global movement for further analysis.

Two abnormalities are of interest: (1) pigs moving too quickly and (2) pigs moving too slowly or being stationary. The former can indicate stress as it may happen when animals are encouraged to move too quickly or are agitated by external disturbances. The latter may indicate that an animal is injured or sick, or that there is an obstacle in its path. Identifying abnormally moving pigs will allow for possible interventions to ensure the welfare of the animals. The suggested method can be used for real-time monitoring although additional research is needed to account for the correlation between MAH from consecutive frames.

2. Methods and materials

2.1. Data

In this study, pigs were video-recorded in a slaughterhouse just after unloading from trucks. The daily process was recorded to capture the normal pig movement. A GoPro HERO2