Farm Animals Monitoring Tool based on Image Processing Technique

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Abstract. This paper describes camera based systems and image processing technique as a monitoring tool for farm animals. Image based systems were used to automatic measure the activity and occupation indexes of piglets and broilers chickens. Experimental results were presented in a form of two case studies: 1) Understanding the effect of environmental enrichment in piglet's activities - the study was conducted in two selected pens of a fattening room. The activity of 14 Dalland piglets was recorded continuously for a total of 5 days. On the second day environmental enrichments were introduced in the form of two wooden logs and a chain. 2) Understanding the effect of light intensity on broiler chicken's activities - in a total of 62 Ross 308 broiler chickens (equal number of female and male) kept on a 16 h photoperiod treatments. The light intensity schedule varied according to the age of the chickens. For chickens with 15 days old the light-dark schedule alternate every 4 hours between 5 lx and 100 lx. For chickens with around 21 and 40 days old the light conditions alternated every 2 hours. In both study cases the activity index recorded the total amount of movement at a group level. Piglets increased their movements and playing behaviour when environmental enrichments (wood logs and chain) were introduced to the pens. Broiler chickens showed higher activity indexes during periods of 100 lx than 5 lx when light intensity alternated.

1 Introduction

In the past, livestock management decisions were made entirely on the audio-visual observation, judgment and experience of the farmer [7]. However, due to price competition the number of animals and the scales of animal farms have increased. This increasing scale of farms and the corresponding high number of animals has intensified the administrative, technical, organizational and logistic workload of the farmer who has, consequently, less possibility to monitor his animals by audio-visual scoring. One of the objectives of Precision Livestock Farming (PLF) is to develop on-line tools for fully automatic and continuous monitoring of farm animals during their

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life [1]. PLF consists of measuring variables on the animals, modelling these data to select information and calculate specific parameters, and then using these parameters in real time for monitoring and the models for controlling purposes. Image analysis is one of the tools used in PLF for monitoring. Nowadays, image processing technique is relatively inexpensive, which is an advantage, since it requires only some cameras and computers, and furthermore it doesn't interfere with the animals' environment. The aim of these technical tools is not to replace, but to support the farmer who always remains the crucial factor in a good animal management system. Animals can be monitored as individuals or as a group. When single animals are observed, automatic monitoring tool can be developed by, firstly, extracting features from the images in order to model the animal. The models of the animals can be simple or more complex depending on the application. A pregnant sheep, for example, can be represented as a line for predicting the time of birth, an ellipse is enough for real time detection of scratching behaviour in caged poultry [11], and the contour and four points for describing altered gait in laboratory mice [10]. After the biological system is described in a simplified form by a real time model, the next step consists in developing a second dynamic model able to detect and predict specific behaviours. However, the individual approach is not feasible anymore in the case of large number of animals observed due to both complexity and the computational demand (for instance, monitoring thousands chickens individually in a poultry house). Therefore, another methodology has to be used. Instead of looking at each individual, the group is now taken into consideration. The activity index, the fraction of the floor space in the pen that contains motion in between two subsequent camera images, and the occupation index, the fraction of the floor space occupied by the animals, are good estimators for analysing the animals' behaviour and their welfare. These indexes have been implemented in a commercial product to evaluate thermal comfort of chickens in real time [4].

The objective of this work was to describe camera based systems and image processing techniques as a monitoring tool for farm animals. Experimental results of occupation index and activity index for both pigs and broilers were presented in a form of case studies. The activity of piglets was measured in response to environmental enrichments while the activity of broilers chickens was measured in response to light intensities.

2 Materials and Methods

Image based systems were developed to measure the activity and occupation indexes of distinct groups of farm animal (pigs and chickens) in practical field conditions.

The initial image processing step applied was the image segmentation in order to extract object shapes from the images and make a distinction between foreground and background regions in the image. With an adaptive threshold method, with threshold value τ_0 based on the image histogram using Otsu algorithm [13] the binary image I(x,y,t) was obtained. In the binary images pixels representing the animals have different values than the one of the background of the image ($I_o = 1$ or $I_o = 0$, respectively).

$$I_o(x,y,t)=\begin{cases}1 & if \quad I(x,y,t)>\tau_0\\ 0 & otherwise\end{cases} \tag{1}$$

The occupation index calculates the fraction of the area occupied by the animals considering the division of the image into different zones.
From the occupation image $I_o(x,y,t)$ the occupation index $o_i(t)$ for the zone Z_i was calculated as the fraction of pixels corresponding to a region of the image occupied by animals with respect to the total number of pixels within the zone Z_i:

$$o_i(t)=\frac{\sum_{(x,y)\in Z_i} I_o(x,y,t)}{\sum_{(x,y)\in Z_i} 1} \tag{2}$$

The idea behind the quantification of the activity index is that the change in colour or grey value of the pixels in consecutive frames provides a good estimation of the activity of animals. The difference of pixel values $I_{diff}(x,y,t)$ between the binary image $I(x,y,t)$ extracted from the video at time t and the one $I(x,y,t-1)$ extracted one frame before at time t-1 was calculated:

$$I_{diff}(x,y,t)=I(x,y,t)-I(x,y,t-1) \tag{3}$$

In order to take into account the small changes of the pixels due to noise, e.g. small lighting variation, a threshold τ_1 was set to 10% of the maximal intensity variation observed in an empty region. In order to compensate drastic changes in pixels' values, e.g. when lights were switched on and off a second threshold τ_2 was added and set to 50% of the maximal activity.

$$I_a(x,y,t)=\begin{cases}1 & if \quad \tau_2>I_{diff}(x,y,t)>\tau_1\\ 0 & otherwise\end{cases} \tag{4}$$

The activity index $a_i(t)$ for the zone Z_i was calculated as the fraction of the 'activity image' $I_a(x,y,t)$ with respect of the total number of pixel of the zone:

$$a_i(t)=\frac{\sum_{(x,y)\in Z_i} I_a(x,y,t)}{\sum_{(x,y)\in Z_i} 1} \tag{5}$$

2.1 Case Study: Monitoring of Piglets in Response to Environmental Enrichment

The study was conducted in a fattening room. The barn was an open-space 4.6 m wide x 6.81 m long, mechanically ventilated and subdivided into 6 pens 2.27 m long and 1.9 m wide each, all equipped with fully slatted floor. The selected pen was positioned at the end of the pig's barn and delimited by the wall 1 m high and 0.2 m thick. A corridor of 80 cm long divided the pen monitored. The pen contained 14

Dalland race piglets in post-weaning period with average weight of 6.4 kg and average age of 23 days at the beginning of the experiment.

An infrared CCD camera (Sanyo Analogue CCD) was mounted 3 m above the floor with its lens pointing downward directly above the corridor separating the two pens to get a top view of both pens in the camera image. The camera was connected to a PC with a built-in frame grabber (Data Translation DT 3210) using a coaxial cable. Images were captured continuously with a resolution of 786 x 586 pixels at a sample rate of one frame per second for a total period of 5 days. Fig. 1 illustrates the facilities and one example of the images obtained by the cameras.

Fig. 1. Illustration of the experimental facilities (left side) and image recorded by the video camera (right side).

Both the occupation index and activity index were then obtained for different groups of piglets in response to the introduction of environmental enrichments in the form of two wooden logs and a chain.

2.2 Case Study: Monitoring of Chicks in Response to Light Intensity

Four boxes (100 cm length x 80 cm width x 100 cm height) kept under the environmental thermo-neutral zone of the chickens were used to house the chicks during the observation periods. Automatic drinkers were placed (15 cm above the floor) in the entrance to each box providing water ad libitum for the chicks. The birds had ad libitum access to a commercial diet via feeders placed 9 cm above the floor (15 cm feeder space/bird). Six 18 W fluorescent luminaries were used in each box. Fig. 2 shows a scheme of the facilities used during the experiment.
The images of the birds were collected with a camera (InterM, CCD Digital Colour Camera VDC413, with an Ernitec 4 mm TVlens F1.2) via a 5 cm diameter hole in the centre of each box, ensuring a central and complete view of each pen. Four images per second were recorded on a time-lapse VCR (Panasonic Time-Lapse S-VHS AG6720A) during the 16 h of light on each experimental day. The video-images were digitalised using a WinTV-PVR-usb-V1.3 image grabber (Hauppauge Computer Works, Inc., 2001–2002). The activities measurements were observed in a total of 62 Ross 308 broiler chickens (equal number of female and male) kept on a 16 h photoperiod treatments. The light intensity schedule varied according to the age of the chickens. For chickens with 15 days old the light-dark schedule alternate every 4 hours between 5 lx and 100 lx Hence the activity of the chickens was recorded during

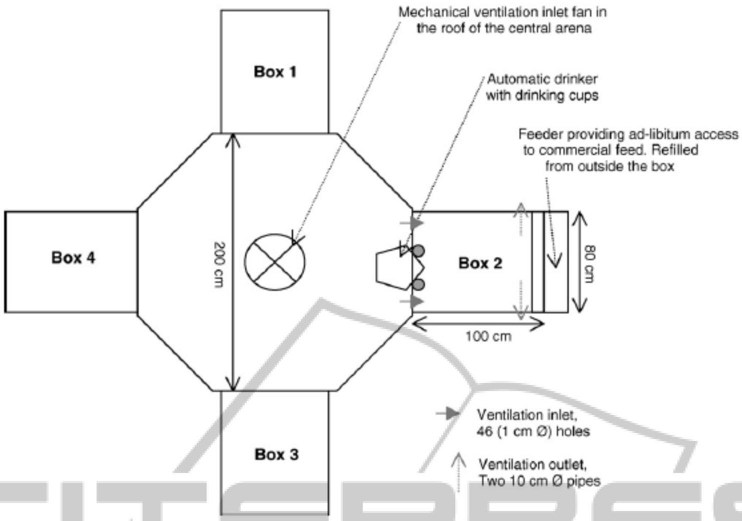

Fig. 2. Illustration of the boxes used to house the chicks [8].

two steps up (5 – 100 lx) and one step-down (100 – 5 lx) in light intensity. For chickens with around 21 days old and 40 days old the light conditions alternated every 2 hours. Hence the group of chickens tested in those groups experienced 4 times steps up (5-100 lx) and 4 times steps down (100 – 5 lx). Further experimental setup details, with complimentary goals (for instance with fixed light intensity treatments), are available at the literature [8]. Both the occupation index and the activity index were then obtained for the group of observed broiler chickens.

3 Results and Discussion

3.1 Effect of Environmental Enrichments on Piglets Activity

The introduction of the environment enrichment affected the dynamic daily activity pattern of the animals. Piglets showed an increase of their activity index with the introduction of environmental enrichments, but a reduction during the next day and back on average after 4 days (Fig. 3). The interest of piglets to the wood logs had decreased over time, but the duration had increased while the attention to the chain had slightly increased as frequency and duration, based on farm observations.
The occupation index, instead, slowly decreased on the day of the enrichment, since the pigs formed different groups around the chain and around each of the wooden stick. Also the occupation index returned to the average after 4 days (Fig. 4).

3.2 Effect of Light Intensity on Broiler Chickens Activity

The total amount of movement observed was corrected for the average size of the

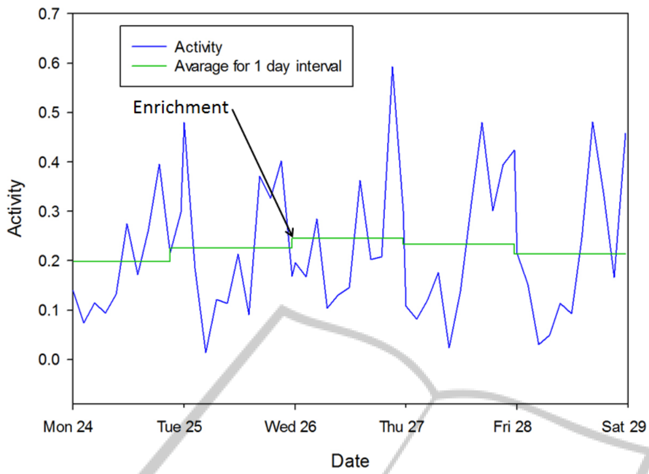

Fig. 3. Activity mean of the piglets calculated continuously during the experiment.

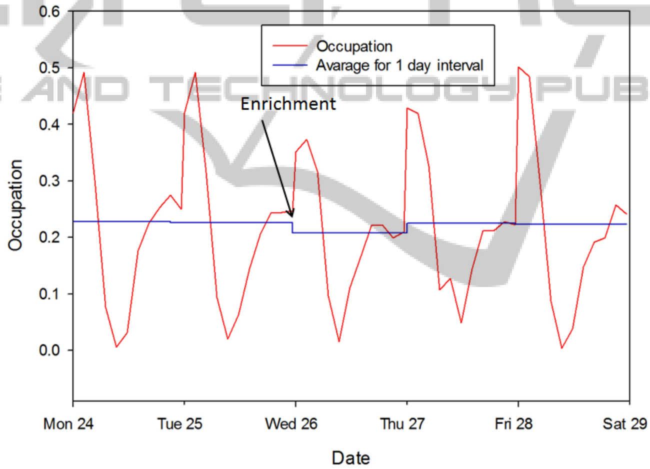

Fig. 4. Occupation mean of the piglets calculated continuously during the experiment.

birds in each box (from the dorsal view of the birds whilst standing) at each age and given in units of area, cm^2. Activity of chickens was affected by changes in light intensity. The Fig. 5 shows on of the results of the activity index over a day at 2-h intervals with details of the relationship between light intensity and activity, as well as, the inherent oscillations in the activity within light environments. It also illustrates that the activity levels during a fixed light intensity of either 5 lx or 100 lx. Complimentary results are available at the literature [7].

The mean activity index of the chickens at group level was significantly higher in 100, lx than 5 lx (ANOVA, $F(1,19) = 29.90$, $P < 0.0001$) during the step-wise changes but, was otherwise, very similar (Fig. 6). Previous studies on layers and broilers have shown a positive correlation between light intensity and activity [5]; [6]; [3].

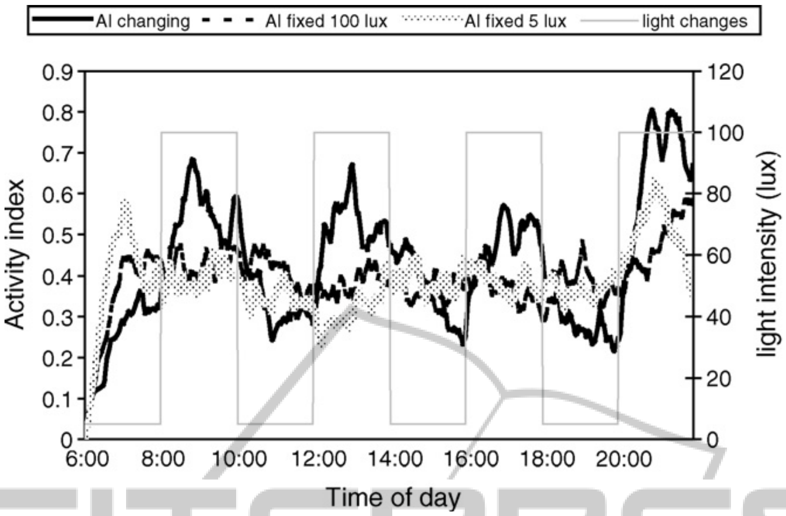

Fig. 5. Results showing the activity index over 16 h light period (06:00 – 22:00) with light intensity alternating between 5 lx and 100 lx each 2 h period [8].

The mean activity level did not differ significantly between male and female birds (ANOVA, $F(1,19) = 3.17$, $P = 0.091$) which is in agreement with previous studies [6]. However male chickens responded faster than females in light intensity changes at 15 and 21-22 days of age. Activity decreased significantly with age (ANOVA, $F(2,19) = 41.26$, $P < 0.0001$) as show in Table 1. The mean activity index was slightly higher for chickens of 15 days old than 21–22 days of age. Previous work has shown a peak in activity at between weeks 2 and 3 of life with a sharp drop in activity thereafter [13]; [2]; [12]. The activity index was very similar in constant light of 5 lx and 100 lx and intermediate to the extremes of the alternating intensity (ANOVA, $F(1,8) = 5.39$, $P = 0.0488$).

Table 1. Mean activity index (with standard error) for male and female broiler chickens at different ages in different light intensity conditions [8].

Factor	Level	Mean activity index (cm2)
Light	5 lx	0.289 ± 0.0207
	100 lx	0.449 ± 0.0207
Sex	Female	0.343 ± 0.0207
	Male	0.395 ± 0.0207
Age	15 days old	0.492 ± 0.0254
	21-22 days old	0.431 ± 0.0254
	40 days old	0.184 ± 0.0254

5 Conclusions

The occupation index and activity index were calculated and used in two different case studies: 1) understanding the effect of environmental enrichments in piglet's activities and 2) understanding the effect of light intensities on broiler chicken's activities. The activity index recorded the total amount of movement at a group level in an automatic objective and inexpensive way, using image processing technique. The results have shown an increase in the activity index for both of the studied cases. Piglets increased their movements and playing behaviour when environmental enrichments (wood logs and chain) were introduced to the pens. However their attention to the wood logs and the chain dropped considerably over time and normal activity level was expressed after four days. The broiler chickens showed significantly higher activity indexes during periods of 100 lx than 5 lx when light intensity alternated. The total amount of activity decreased with age of the chickens. Both, the occupation index and the activity index showed to be useful for assessing general animal behaviour in a group level of farm animals. Moreover, automatic monitoring of broiler chickens and piglets activities, by means of image processing technique serve as an effective tool for support the farmer on taking actions to increase animals' welfare.

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