Use of analysis and processing of digital images for evaluation and control of animal behavior in hot climates

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Abstract: The world production of meats is mainly concentrated in the countries with a hot climate. Among these countries, Brazil, considered "world's breadbasket", is located in the intertropical zone, with hot climates and presents lower thermal amplitude. Brazilian poultry is a leader in the production and export of broilers. Brazil has the second largest cattle herd in the world, has the largest commercial herd besides being the largest exporter of beef. Brazilian swine breeding, among the most advanced production chains in the world, occupy the position of fourth largest producer of pork in the world. Projections for Brazil's meat production sector indicate strong growth in the coming years, with countries in hot climates that will continue to sustain future growth in world meat production, ensuring food security in many countries. One of the factors responsible for the success or failure of animal production is the environment, defined by the sum of all physical and biological factors that affect animals. In these regions of hot climates, climatic factors are among the main limiting factors to the development of animal production, which may compromise animal welfare and productivity indices. Behavioral information can aid in the analysis of problems arising from environmental conditions unfavorable to animals, helping both decision making and the use of different environmental conditioning systems. The introduction of technification in the animal behavior evaluation processes, through the use of video cameras and image processing programs, allowed a better interpretation of the behavioral responses, quickly, accurately and non-invasively, gradually being used with greater frequency in the animal production sectors. The study of animal behavior assumes an important role in animal production, since, to rationalize the breeding methods, management, feeding and facilities techniques have been developed that interfere with animal behavior. In this context, the use of digital image analysis techniques, where the animals themselves are used as biosensors in response to environmental conditions, contributes to the analysis of animal behavior, and consequently also to the assessment of the internal environment of the production in hot weather.
Keywords: animal production, animal welfare, information technology

1 Introduction

World meat production is mainly concentrated in warm-weather countries, in tropical and subtropical areas, it is estimated that more than 50% of the world's total meat production areas (Renaudeau et al., 2012). Among these countries, Brazil, considered "world's granary", is located in the intertropical zone, with hot climates and presents a lower thermal amplitude, conditions that favor animal production.

Brazilian poultry is a leader in the production and export of broilers. Brazil is among the world's three largest

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producers of chicken meat, together with the United States and China, with more than a billion head of broilers and has been maintaining the position of largest exporter for more than a decade the world, shipping to more than 150 countries (IBGE, 2016). The sector employs more than 3.6 million people, directly and indirectly, accounting for almost 1.5% of the national Gross Domestic Product (ABPA, 2016).

Brazil has the second largest cattle herd in the world, behind only India. It has the largest commercial herd with 214 million heads in 2015. It is the largest exporter of beef, with 20% of the total produced placed in the international market for more than 150 countries. The productive chain of beef with 9.5 million tons produced generates approximately 7 million jobs in Brazil (IBGE, 2016).

Brazilian pig farms, among the most advanced production chains in the world, with high technology and total control of processes with high quality standards. The animals are raised in confinement systems, allowing full sanitary control, in addition to respect the international requirements of animal welfare. The cost of production of Brazilian pork is considered the lowest in the world when compared to the largest producers. For all this, Brazil has established itself as the fourth largest producer and exporter of pork in the world. Producing 3.3 million tons annually, of which 600 thousand tons are exported to more than 70 countries (ABPA, 2016).

Projections for Brazil's beef industry indicate strong growth in the coming years, with countries in hot climates that will continue to sustain future growth in world meat production, ensuring food security in many countries. One of the main factors responsible for the success or failure of animal production is the environment, defined by the sum of all physical and biological factors affecting animals (Baêta and Souza, 2010; Neves et al., 2010). In these regions of hot climates, climatic factors are among the main limiting factors to the development of animal production, which may compromise animal welfare and productivity indices (Renaudeau et al., 2012).

Animal welfare is one of the main needs that producers must meet in order to ensure both consumer interests and greater market share. Production and quality in animal husbandry are related to animal welfare, therefore, breeding systems must raise their levels and production methods, while meeting the needs of animals.

As the physiological variables are difficult to measure, under field conditions, the study of behavior has shown to be the most feasible to infer about the welfare levels of the animals housed. As the animal is strongly influenced in its behavior by the external environment, knowing how it acts on the animal through behavior, it is possible to identify and quantify the welfare of animals.

Behavioral information can aid in the analysis of problems arising from environmental conditions unfavorable to animals, helping both decision making and the use of different environmental conditioning systems (Berckmans, 2013; Shao and Xin, 2008). The introduction of technification in the animal behavior evaluation processes, through the use of video cameras and image processing programs, allowed a better interpretation of the behavioral responses, in a fast, precise and non-invasive way, gradually being used with greater frequency in the animal production sectors.

The study of animal behavior assumes an important role in animal production, since, to rationalize the breeding methods, management, feeding and facilities techniques have been developed that interfere with animal behavior. In this context, the use of digital image analysis techniques, where the animals themselves are used as biosensors in response to environmental conditions, contributes to the analysis of animal behavior, and consequently also to the evaluation of the internal environment of the production in hot climate.

2. Animal behavioral study from digital images

Animal behavior until recently was measured by visual observation of animals, which consumed more time, was subjective and very susceptible to human error, a method that due to human presence the birds may have their natural behavior inhibited, generating non-response reliable (Abrahamsson, 1996; Falco, 2010).

Among the methods used to study the behavior of animals, the analysis of images has been highlighted. Automation, through video cameras and image-interpretation programs, has made it possible to better interpret animal behavior without the need to be around them or to bother them (Kashiha et al. 2013).

According to Shao and Xin (2008), the evaluation and the interactive controls of the thermal comfort of the animals by the image analysis overcome the problems inherent to the conventional method, since the animals themselves are used as biosensors in response to the reflexes of the environment through behavioral analysis.

Image analysis is the set of methods and techniques through which computational systems can be able to interpret images, providing accurate measurements based on pixel count (Filho and Neto, 1999). The main objective of image analysis, whether performed by a human observer or by a computer analysis system, is to extract useful and relevant information for each desired application (Sergeant et al., 1998; Esquef et al., 2003), so there is no standard formula for all situations.

A set of specific algorithms is necessary in the analysis and interpretation of images, where these algorithms use different techniques, and their sequence generates results for a specific set of images, and can't be generalized to other studies (Gonzalez and Woods, 1992).

It can be said that the analysis of images is the process of quantitative measurement of a certain aspect of the image, in order to generate information. While in the other processes of image processing the input and output of the system are images, in the analysis the output may not be an image, but a graphic or a value referring to the property of the image to be estimated.

Image processing and analysis consists of several steps, illustrated in Figure 1, such as: acquisition, preprocessing, segmentation, representation and description, recognition and interpretation, all of which are steps associated with a knowledge base, which is depending on the application, the size and complexity of which may vary significantly (Pedrini and Shwartz, 2008).

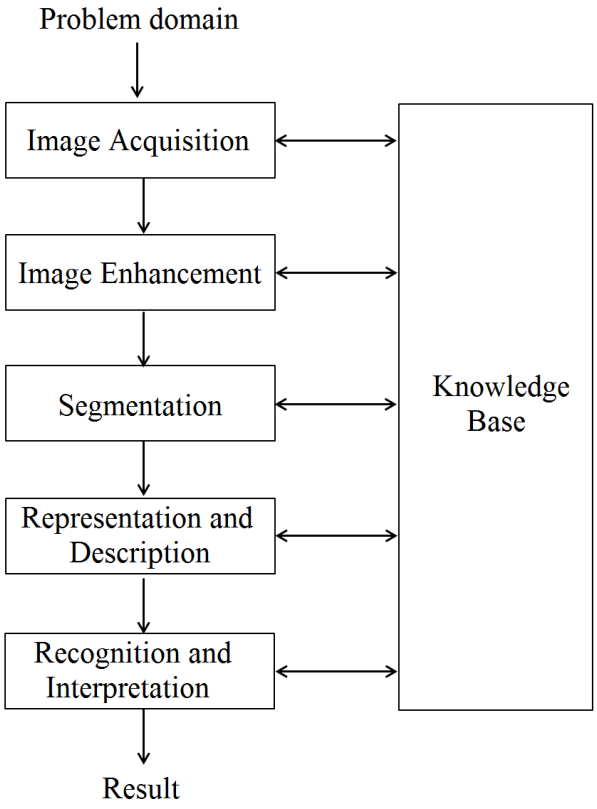


Figure 1. Stages of image processing system.

3. System of acquisition and processing of images

According to XIN et al. (1998), a system for the analysis of images should consist of a camera, an image capture card installed in a computer and a program that performs the acquisition and all image processing.

Devices play an important role in an image processing system, and can be used for acquisition, storage, processing, transmission and display of images (Pedrini and Shwartz, 2008).

In artificial vision there are one-dimensional cameras (line scan cameras) and two-dimensional cameras (area cameras). Most of the applications in which image analysis and processing are used are area cameras. Within the camera classes there are numerous choices to make such as, for example, color or monochrome, angle of view, field of view, resolution, among others (Albuquerque et al., 2012).

The acquisition board is a generic term for the interface of the camera to the computer and must be determined by camera characteristics, computer hardware (the card must be compatible mechanically and functionally as a computer system used) and whether or not it has image processing integrated (Albuquerque et al., 2012).

The processing of images after acquisition can be performed by the capture card itself or by software that has this purpose, where the choice of suitable software is in function of the purpose and speed of the image processing.

Images require high storage capacity. For example, a 1024 x 1024-pixel color image requires, 3 Mbytes for storage, and a 1 minute video, consisting of 512 x 512 pixel images, displayed at a rate of 30 images per second, each pixel Represented by 24 bits, requires around 1.4 Gbytes of storage space (Pedrini and Shwartz, 2008), with this there is need of computers and storage devices with great capacities.

Factors such as the research objective, characteristics of the location of the images (type of illumination), device quality, acquisition cost and availability in the market may influence the choice of equipment and software used.

4. Analysis and processing of digital images

Acquisition and storage

The acquisition step captures the image by means of devices or sensors and converts it into a suitable representation for subsequent processing. The main devices for acquisition of images are video cameras, medical tomographs, satellites and scanners. Among the aspects involved in this step is the choice of sensor type, scene lighting conditions, resolution and the number of gray levels or colors of the scanned image. The acquisition devices may have very different characteristics in terms of spatial resolution, operating speed, accuracy and cost (Pedrini and Shwartz, 2008).

Preprocessing

The image after the acquisition may present imperfections or degradations due to the lighting conditions or depending on the chosen device. Therefore, the preprocessing step has the function of improving image quality through the application of techniques for noise performance, correction of contrasts or gloss and smoothing of certain properties of the image (Pedrini and Shwartz, 2008).

The techniques involve two main categories: methods that operate in the spatial domain and methods that operate in the frequency domain. Techniques in the spatial domain refer to the image plane, and the approaches in this category are based on the direct manipulation of the pixel of the image, while the techniques of processing in the frequency domain are based on the modification of the image with application of the Fourier transform (Marcelo, 2007; Pedrini and Shwartz, 2008).

It is common to highlight certain characteristics of an image to combine different techniques (filter application, grayscale transformation) and are in these two categories.

Segmentation

The segmentation stage performs the extraction and identification of areas of interest contained in the image. The purpose of segmentation techniques is to divide the image into its various constituent parts or segments (objects and regions). The level or number of divisions applied in the image varies according to the application, and is usually performed until a sufficient separation level is reached between the objects of interest in the analyzed scene (Gonzalez and Woods, 1992).

A segmentation process that correctly identifies the location, topology, and shape of objects is a critical requirement for information resulting from an image analysis system to be reliable. After segmentation, attributes with area, shape and texture can be extracted from the objects and used in the analysis process (Pedrini and Shwartz, 2008).

Segmentation is considered, among all stages of image processing, the most critical stage of information processing. Segmentation algorithms are based on the discontinuity (detection of isolated points, lines and edges) and similarity (thresholding and segmentation of regions) (Cordeiro et al., 2010).

This step plays a very important role in image processing, it is usually the first vital step to complete before a series of tasks such as feature extraction, classification, description, etc. can be performed. Targeted objects are generally referred to as the foreground and the rest of the image in the background (Solomon and Breckon, 2013).

Processor an image so as to segment a number of objects, possibly in different sizes and shapes, is a difficult task and extremely dependent on the correct extraction of characteristics of objects, especially in noisy images. Noise may lead to

segmentation methods that distort object shapes, compromising their recognition, such that distinct regions could be incorrectly identified as a single region, otherwise a homogeneous region could be divided into smaller regions (Pedrini and Shwartz, 2008).

Representation and description

After the image has been segmented into objects and regions, resulting pixel groupings are usually represented and described in a format appropriate for the later step. An object can be represented in terms of its external characteristics (edges) or internal characteristics (pixels that make up the object). The description depends on the representation adopted and should allow the characterization of its form without ambiguity with a reduced number of characteristics or measures extracted from the object (Pedrini and Shwartz, 2008).

Adequate representational structures should be used to store and manipulate the segmented objects of interest in the image, in addition to simplifying the calculation of certain descriptors. The description process aims at the extraction of characteristics or properties that can be used in the discrimination between classes of objects (Pedrini and Shwartz, 2008). The descriptors are divided into two groups: edge descriptors and region descriptors.

Edge descriptors, sensitive to image resolution, are based on geometric properties, and most edge detectors are fundamentally based on the use of differential gradient filters (Pedrini and Shwartz, 2008; Solomon and Breckon, 2013). However, these filters do not determine the edges themselves, merely indicate their likely occurrence. In real edge detection factors may complicate identification such as edge strength, noise effects and edge discontinuity (Solomon and Breckon, 2013).

In region-based descriptors, according Pedrini and Shwartz (2008), the pixels located inside the region or object are considered in the descriptor calculation, instead of using only the pixels that form the border of the region.

Recognition and interpretation

The last step involves recognizing and interpreting the components of an image. Recognition or classification is the process that assigns an identifier or label to the objects of the image, based on the characteristics provided by its descriptors. The interpretation, however, consists in assigning a meaning to the set of recognized objects (Pedrini and Shwartz, 2008).

5. Use of analysis and image processing in poultry

The image processing of birds housed inside aviaries or in research environments is of great importance in the advancement of studies and development of poultry activity.

In the different steps in the image processing, several algorithms can be elaborated, with different intentions, for example: to develop classifiers capable of separating the images in two classes, being birds in comfort (condition of well being) and birds in thermal discomfort (absence of well-being, analyze the density of birds in a given region (feeder and water fountain), determine the body mass of birds, among others.

Most analysis of images of the poultry environment is of interest to birds, where the "bottom" of the image will include the feeders, drinking fountains and floor. Several works have been developed in the analysis of the behavior of the birds based on images, which employ different methodologies in the analysis and processing.

Mogami (2009) through image analysis developed a methodology to evaluate the welfare of broiler chickens; For that purpose, created two frequency indices at the feeder, the ICRC (feeder competition index), in order to measure the number of chickens present in the feeder region, and the ICEC (effective feeder competition index) to determine the number of heads inside the feeder. Figure 2 shows the images in the processing step.

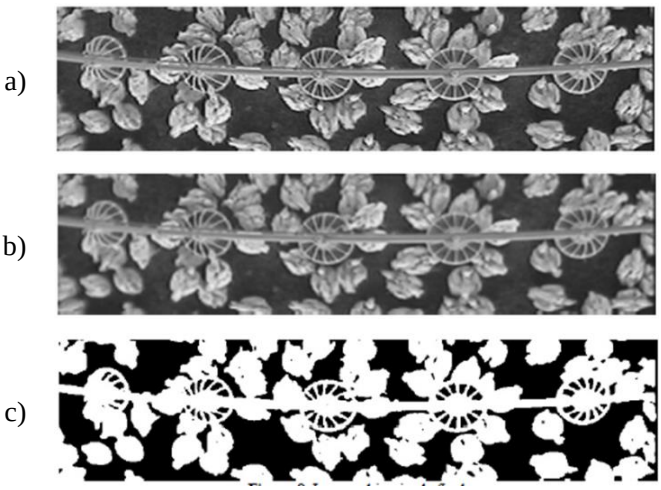
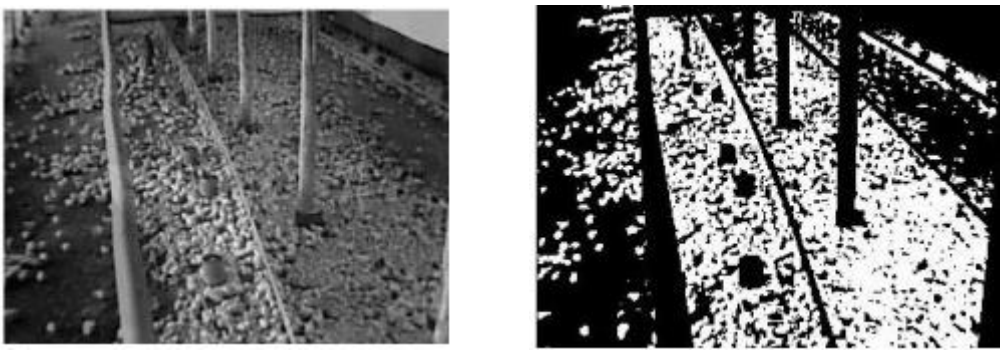


Figure 2. Intermediate images during processing. In sequence: a) resized image, b) filtered image and c) binarized image.
Source: Mogami (2009).

Cordeiro et al. (2011) analyzed and quantified the behavior of chicks of broilers kept under heating, using descriptors of grouping characteristics and dispersion in the image processing. For this study, it used video cameras with a resolution of 510 x 492 pixels, and the implementations of the algorithms in the MATLAB R12® computer program. Figure 3 shows the grayscale (a) and binarized (b) images of the image analysis process.



(a) (b)

Figure 3. Gray scale images (a) and binarized (b).
Source: Cordeiro et al. (2011).

Sevegnani et al. (2005) by means of images evaluated the feeding behavior of broiler chickens in relation to the search for the feeder and drinker, when subjected to stress situations in a climatic chamber, using the Video Cap® software.

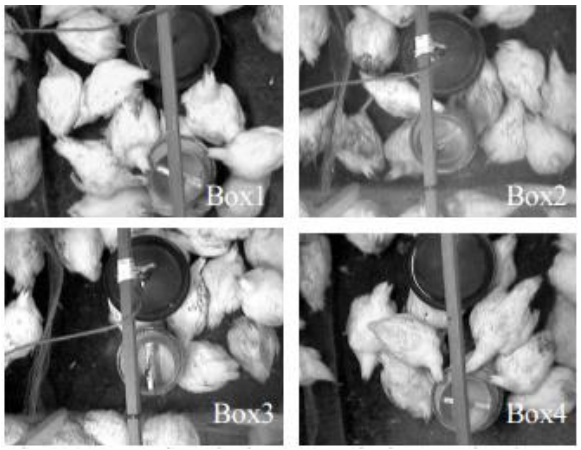


Figure 4. Images analyzed in the Video Cap® software.
Source: Sevegnani et al. (2005).

Figueiredo et al. (2003) developed a methodology for evaluating poultry behavior through an artificial vision system to extract the response to temperature and feeding behavior of commercial poultry. Two different types of surveillance cameras were used to acquire the images, the images were stored and the algorithms implemented in the LabVIEW 6.1 and MATLAB Release 13 programs, respectively. In Figure 5 the images are shown during processing.

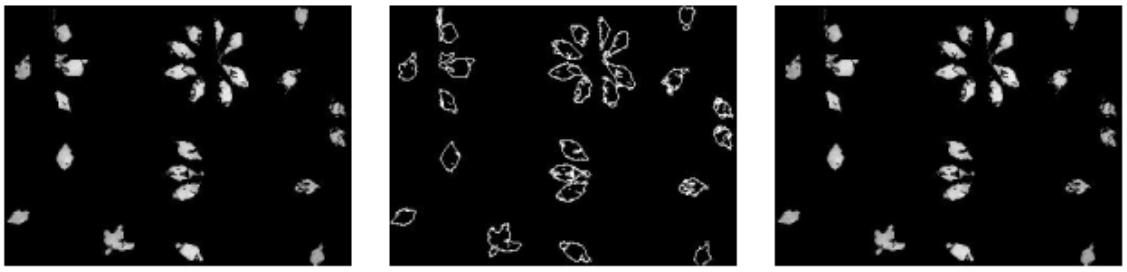


Figure 5. Temporary images during processing.
Source: Figueiredo et al. (2003).

Rodrigues et al. (2007) developed a methodology to evaluate the behavior of laying hens under different stress conditions, observing behavioral profiles and dynamics of the birds in a space-time relation with the application of computational vision and use of colors in the evaluation of the behavior of the animals in large aviaries.

Amaral (2012) developed a methodology based on the analysis of digital images to verify the feeding behavior of European quails cut in different environmental conditions. The algorithm implemented in the software MATLAB 6.5® measured the frequency of use of the feeder to verify the influence of the thermal environment on the feeding behavior of the birds. Figure 6 shows the steps of the image analysis process.

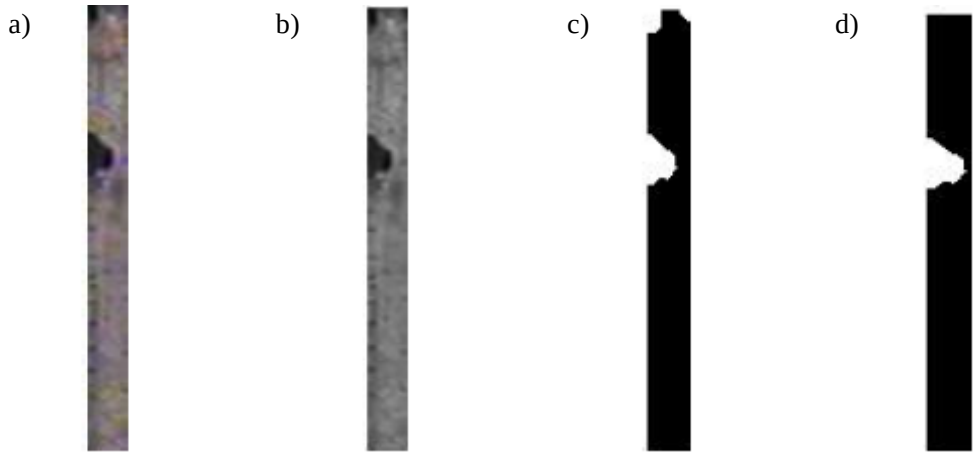


Figure 6. Image of an isolated feeder (a), represented in gray scale (b), in binary image with presence of noise (c) and, image ready for counting objects (d).
Source: Amaral (2012).

6. Final considerations

The study of animal behavior assumes an important role in poultry production, since in order to rationalize the breeding methods, management, feeding and facilities techniques have been developed that interfere and are also influenced by the behavior of the birds.

In this context, the use of digital images analysis of the birds contributes to the analysis of the animal behavior, and consequently also in the evaluation of the internal environment of the aviary, functioning as an indicator of improvement in the production system.

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