Computers and Electronics in Agriculture 153 (2018) 33–45

Contents lists available at ScienceDirect

Computers and Electronics in Agriculture

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

Original papers

Algorithm of sheep body dimension measurement and its applications based on image analysis

A. Lina Zhang[a,b], B. Pei Wu[a,*], C. Tana Wuyun[a], D. Xinhua Jiang[c], E. Chuanzhong Xuan[a], F. Yanhua Ma[a]

[a] College of Mechanical and Electrical Engineering of Inner Mongolia Agricultural University, Inner Mongolia Engineering Research Center for Intelligent Facilities in Grass and Livestock Breeding, Hohhot 010018, China
[b] College of Physics and Electronic Information Science, Inner Mongolia Normal University, Hohhot 010022, China
[c] College of Computer and Information Engineering, Inner Mongolia Agricultural University, Hohhot 010018, China

ARTICLE INFO

Keywords:
Computer vision
Image processing
Measuring points extraction
Body size measurements
Small-tailed Han sheep

ABSTRACT

Body size parameters of sheep can reflect its growth development, production performance and genetic characteristics. Therefore, the body size measurement is great significance in sheep breeding. In this study, a measuring method based on vision image analysis for the body size of sheep is proposed, which can be practically applied in farm environment without disturbing the animals. This approach is based on computer-assisted visual image capture in a position-limit apparatus, and based on an automatic foreground area extraction algorithm known as simple linear iterative clustering (SLIC) SuperPixels and Fuzzy c-means (FCM) clustering, a center line of flexible symmetrical body extraction algorithms, as well as measuring points extraction algorithms. The test results for 27 small-tailed Han sheep chosen randomly from herd show that the method for foreground extraction can get segmentation images with well-remained boundaries. Detection algorithm of the center line of sheep body in top view has a relatively high adaptability. The extraction of measurement points in different postures for sheep's body size has a better stability and accuracy, the maximum average relative errors between the detected and measured values of body height, rump height, body length, chest depth, chest width and rump width are 1.13%, 1.54%, 2.03%, 4.45%, 2.25% and 2.41%, respectively. The use of both left view and right view can improve the precision of the measurement, and the values from one test may have a greater deviation from the actual values due to the variety of sheep body posture, but the accuracy can be improved by averaging the measurements repeated for many times. The results also show that measurement of sheep size based on vision image analysis is feasible, and it can ensure accuracy, reduce workload and sheep stress compared to the method conducted by man. Prediction result of live-sheep weight based on body size shown that the parameters got by image processing can be used for monitoring the growth of sheep.

1. Introduction

The body dimension of livestock can reflect its body profile, structure and development status, and also can show the livestock's physiological function, production performance, disease resistance, and the adaptability to external living conditions, etc. (Liu et al., 1998). Therefore, the livestock body size is widely used in its identification, breeding and sale. The conventional measurement of animal body size is often done manually, using the tools such as measuring rods, tape measure, and circular gauges to measure the parameters such as body height, body length, chest girth, cannon circumference, rump height, chest depth and chest width. With the upgrading of information-aware technology and precision breeding level, the way in acquisition of body size data for livestock are heading to a non-contact, high precision and high degree of automation (He et al., 2016).

Sheep industry, following the dairy industry and cashmere industry, is a new growth way for local economic development in Inner Mongolia and the surrounding western region in China. In recent years, the intensive facilities for sheep breeding has been greatly developed owing to the unique regional and resource advantages, overall drylot feeding and large-scale farming have become the trends of sheep industry (Xuan, 2016). The individual difference in the group should be considered in large-scale farming to achieve a high yield, high quality, high efficiency, safety and sustainable development.

* Corresponding author.
E-mail address: jdwp@imau.edu.cn (B. Pei Wu).

https://doi.org/10.1016/j.compag.2018.07.033
Received 28 January 2018; Received in revised form 21 July 2018; Accepted 24 July 2018
0168-1699/

Table 1
Usually selected parameters of body size for sheep.

Target	Object			Critical body size
	Breed	State	Sex	
Estimated weight	Alpagota	16–136 months	Rams/ewes	Withers height, chest depth, body length (Paolo et al., 2014)
	Menz sheep	Yearling	Ewes	Withers height, body length, rump width (Gizaw et al., 2008)
	Zulu sheep	Adult	Rams/ewes	Chest girht, withers height, chest depth and body length (Mavule et al., 2013)
	Dazu black goats	Adult	Rams	Chest width and cannon circumference (Chen et al., 2008)
			Ewes	Chest girht (Chen et al., 2008)
Evaluated growth performance	Duolang lamb	Per-weaning	Rams/ewes	Chest circumference, Chest depth and body length (Gao et al., 2009)
Stimated meat performance	Cuban Creole goats and their crossbreds	Adult	Adult	Chest width, rump width and chest depth (Chacón et al., 2011)
	Santa Ines sheep	Carcass	Rams/ewes	Chest girht, rump height and chest depth (Filho et al., 2016)
Estimated kidding number	Dazu black ewes	Primiparous	Ewes	Chest girht and withers height (Chen et al., 2009)
Identification of breed	Blackbelly, Dorper, Katahdin, Pelibuey	4.7 ± 0.5 months 7.6 ± 0.5 months	Rams/ewes	Heart girth, abdominal girth, neck girth, loin width, and metacarpus and metatarsus circumference (López-Carlos et al., 2010)
Estimated heritability	Fat-tail sheep	Adult	–	Withers height and body length (Bai et al., 2011)
Selective breeding	Plateau Tibetan sheep	3 months Yearling 3 years old	Rams/ewes	Withers height, body length and chest girth (Yan et al., 2015)

There are some wide extensive researches on sheep breeding based on body size around worldwide (Wynn and Thwaites, 1981; Aziz and Sharaby, 1993; Janssens and Vandepitte, 2004, Jiang, 2004; Salako, 2006; Bingöl et al., 2012; Zhang et al., 2012). A variety of analytical methods were used for morphological evaluation and trait extraction, provided a guidance in animal breed selection and production. However, for traditional body measuring method, it is not only with a heavy measuring workload, but also has a strict demand for sheep standing posture, also the direct contact with sheep is stressful and harmful to the sheep, resulting the decline of production performance, the increase of disease, even death, heavily influenced the individual sheep as well as herd growth development, and increased the spread of zoonotic disease risk. In view of this, the techniques of measuring livestock's body size have drawn the attention of scholars across the world. John C developed a method for determining the characteristics of animal skeletal structures based on optical and acoustical devices (ultrasound) (John, 2011), and using X-ray imaging technique for bone size determination (Cloete et al., 1998). However, ultrasonic imaging was still unable to realize non-contact measurement, and X-ray imaging technique has flaws of cell destruction and higher environmental demands. Therefore, optical based principles of animal body measurements have been emphasized and adopted, e.g. Doeschlwilson et al. (2004), measured pig's plan area and length of different body parts based on machine vision. Zwertvaegher et al. (2011) measured nipple morphology of dairy cow using CCD imaging and computer image analysis. Guo et al. (2014) used the point cloud equipment to measure the cow's body size. Through the literature study, it is known that the measurement based on visual principle is only focused on cattle and swines, but the feasibility of using machine vision technology for the live livestock body measurement has been proved. In recent years, the computer vision technology has been started to apply to the sheep body measurement, e.g. Zhu Lin et al. used embedded machine vision technology to measure the sheep height and body length (Zhu et al., 2014). Paolo et al. (2014) constructed a binocular stereoscopic vision system to assess the size and body weight of live sheep. Khojastehkey et al. (2016) based image processing technology to assess newborn lamb body size, and to estimate the effect of body size on the population genetic performance. The machine vision application in the field of automatic detection not only owns the visual function of human eye, but also performs like a part of human brain, which is just to meet the adjustment demands on the measurement of body size for live livestock.

In previous studies, there were some researches on sheep body dimension measurement based on visual technology, but the automation level was low and the detected parameters were limited. How to achieve more body size parameters through the non-contact, high precision and high automation measurements, to sort sheep and to automatically identify the measuring points on the profile are becoming the key questions. The objective of this research is to develop an algorithm of body dimension measurement that can be efficiently applied in the real farm environment without contact with sheep, and the obtained sheep body dimension is suitable for the conformation appraisal.

2. Material and methods

2.1. Sheep body dimension

The measurement of sheep body size was originated from the physical appearance assessment used to describe the sheep's shape in spatial dimension (Zhang et al., 2016a,b,c). The study mainly focused on the growing development characteristics and the correlation between body size and growth, and the hereditary performance of individual body parameters. In order to make the assessment more objective, the body size measurement requires the sheep with an empty stomach. The commonly used body sizes were classified into four categories: length, width, height and circumference, see Table 1.

2.2. Data collection

The tests were conducted at Hailiutu sheep farm affiliated with Inner Mongolia Agricultural University. The farm is located in Beishizhou village of Tumd, Hohhot, Inner Mongolia, longitude 111°22′30″, latitude 40°41′30″, and served as China - Canada Demonstration Project on Science and Technology Innovation in Sustainable Agriculture: Construction Base of Mutton Sheep. The tested animal was 27 small-tailed Han sheep aging from 12 to 36 months with mean weight of 65.5 ± 9.8 kg, which is of a meat and fur sheep breed originated from Mongolian sheep in ancient north China (Ovis aries), were randomly chosen from herd.

Sheep is a high gregarious animal and eager to form group among familiar individuals (Zhao, 2005; Zhang et al., 2016a,b,c). In this paper, a new method for the measurement of sheep body size in a restricted space was proposed, which is to establish a specific structured device to limit the sheep in a certain space, and then use the pre-installed CCD cameras at the device to take the sheep's images in three directions (top, left, and right) under the natural light condition, as shown in Fig. 1.