Machine Vision-enabled Yak Weight Estimation on Edge Devices

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RESEARCH

Machine Vision-enabled Yak Weight Estimation on Edge Devices

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Abstract

In the field of stock farming, body dimensions and weight of a yak may reasonably reveal its growing characters, productivity and genetic characteristics. However, it is arduous for the herdsman to manually measure the body and dimension of yaks. Fortunately, with the development of mobile computing and edge devices, it is preferable and possible for the herdmen to estimate the yarks weight and size with handheld devices (e.g., mobile phones).

This paper aims at providing machine visual-based yark body height and weight estimate method for edge devices. In our method, to begin with a foreground image of the yak is extracted; and measuring point identification is carried out to identify measuring points of the yak. Then, a ratio of its body dimensions is acquired. Both body dimensions and weight of the yak are acquired through comparison with relevant data. 25 yaks in different age groups were randomly selected from a herd to perform experiments. As indicated by corresponding experimental results, the foreground extraction approach has the potential to generate split images with good boundaries. As for the measuring point identification method selected for the yak, it features preferable accuracy and stability. For example, estimated values of its standing height, body length, chest depth, hipcross height and body weight, average errors between the measured values and them are proven to be 1.95%, 3.11%, 4.91%, 3.35% and 7.79% respectively. By contrast to the traditional measuring approaches, the proposed method may improve measurement efficiency and reduce stimulation caused by manual measurement to the yak.

Keywords: Yak; Three-River-Source; Machine Vision

1 Introduction

Body dimensions and weight of the livestock not only reflect their body outlines, structures and physical conditions, but also embody their physiological status, productivity, disease resistance and adaptation to external living environment, etc [1]. Moreover, they have been also extensively applied in evaluation, reproduction and sales areas. In recent decades, body dimensions and weight measuring technology for the livestock plays a critical role in enhancing animal husbandry production [2]. In addition to directly revealing production traits of the livestock, accurate estimation of their body dimensions and weight is even a key basis for making breeding plans for domestic animals.

Globally, animal sizes have been widely investigated and various analytical methods been adopted to appraise animal morphology and traits. They provide guidance for animal breed selection and animal production [3–5]. However, traditional measuring methods both require high workload, but raise stricter requirements for standing postures of an animal. Besides, direct contact with animals as required by these methods does lots of harm to them, which may further give rise to productivity decline, an increase in diseases and even death among the animals. All these severely affect growth and development of individual animals and the herd on one hand; it is also much more likely to spread zoonotic diseases on the other hand.

In this regard, it is urgent to propose easy-to-handle, lightweight methods to precisely estimate the weight of the livestock. Thankfully, this is made to be true with the proliferation of mobile and edge computing [37–42].They normally utilize sensor networks, image processing and machine learning technologies to collect and processing livelihoods information.For example, a method that was proposed based on optical and acoustic devices (ultrasonic waves) by John C. can identify skeletal structure characteristics of animals [6]; and, X-ray imaging was utilized by CloeteS.W.P to determine bone sizes [7]. Nevertheless, ultrasonic imaging is still incapable of realizing non-contact measurement; and,

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Table 1 **Common Morphological Parameters of Yaks**

Items	Description	Measured by
Standing Height	Vertical height from point of withers (T) to ground	Biltmore Stick
Body Length	Distance from a point of shoulder (C) to a point of the buttocks (TX)	Tape
Chest Depth	Chest height measured along rear end of the shoulder blade (X)	Biltmore Stick
Chest Circumference	Chest perimeter measured along rear end of the shoulder blade (X)	Tape
Hipcross Height	Vertical height from a central point of two lions to the ground	Biltmore Stick
Cannon Circumference	Horizontal perimeter measured at the finest first $1/3$ part (GW) of a cannon in left fore of the yak	Tape

Figure 1 Description for Yak Body Measurement Points.

Table 2 **Common Morphological Parameters of Yaks**

Point	Description
T	Point of withers
X	Point rear to the scapula
G	Lowest point
W	Lower intersection point of chest depth and the yak
C	Point of shoulder
TE	Central point of two lions
TD	Lower intersection point of hipcross height and the yak
TX	Point of buttocks
GW	Point of the first $1/3$ part in cannon of the left fore

the X-ray imaging has defects of cytoclasis and raising more rigorous requirements for environment. For this reason, body measurement for animals is fulfilled by Doschlwilson et al. depending on principles of optics [8]; by virtue of a machine-vision-based method, Zwertvaeg-her et al. succeeded in measuring lengths of different body parts of a swine [9]; and, Wang et al. used a Xtion sensor to analyze and measure swine morphology [10]. For the past few years, computer-assisted image acquisition and processing have been extensively applied in animal husbandry to obtain body measurement parameters of animals. Subsequently, such parameters are utilized to estimate their weight. This has become one of the most popular method in this field. In terms of Paolo et al. A stereo binocular visual system is established to estimate sizes and weight of live goats [11]. On the basis of an image processing technique, Khojasteh-key evaluates body sizes of newborn lambs and figure out influence of body sizes on their genetic characters [12]. With rapid economic progress in Western China, yak breeding industry is gradually developed from a situation where plot-based culture and a free-ranging pattern coexist to large scale breeding. In this context, differences in breeds, ages, fetal times, lactation stages among the individuals should be taken into account for the latter. As the cost of manpower, fodder and dung disposal increases and dairy safety issues are increasingly prominent, large-scale breeding proposes stricter requirements for feeding management modes. Hence, precision breeding supported by information technology is inevitable in the process of modern farming development [13]. Furthermore, information perception and analysis for individual animals is the key to precision breeding. By accurately obtaining information (e.g., respiratory conditions, postures and movement) of individual animals in a real-time manner, their growth, health status and gestation can be objectively evaluated. In this way, relevant prevention and treatment measures such as human intervention can be taken timely, so that potential losses may be minimized.

Growth of the yak is basic biological characteristics of this breed and serves as an important embodiment to their economic values [14]. Considering that the yak production is completed in a highland ecosystem with poor stability, their growth is featured with distinct spatial and temporal heterogeneity. Relevant investigations assist us in minimizing errors of body measurement parameters that are obtained and enhancing sensitivity to weight parameter acquisition, so as to make it convenient for us to diagnose and prevent health problems during livestock breeding.

As mammals living at the highest elevation in the world, yaks are mainly distributed along the Himalayas and on the Qinghai-Tibet Plateau, that is the alpine region at an altitude ranging from $3,000m$ to $5,000m$. Under the circumstance that yaks are rather wild and free-ranging in most cases, it is very difficult to obtain their body measurement parameters and weight by common methods. Here, it is aimed at developing a portable body dimensions and weight measuring algorithm that can be embedded in a portable device, so as to successfully acquire body measurement parameters of yaks outdoors. In a word, such an algorithm can be effectively applied in an actual breeding environment to gain body dimensions and weight of yaks in conditions of reducing human interventions and less contact with them.

2 Materials and Methods

2.1 Body Dimension and Weight Measuring Methods for Yaks

Regarding animal husbandry research and production, certain characteristics of the research object are frequently described by an index [15]. Weight and body measurement to assess health conditions and genetic characters of yaks. Body dimension of a yak is commonly divided into six aspects, including standing height, body length, chest depth, chest circumference, hipcross height and cannon circumference. For details, please see Table 1 and Figure 1.

Before body measurement parameters are evaluated, feeding should be ceased 12 hours earlier to ensure that the yaks are in a fasting state. For each yak, the parameters should be measured for three times and an average value was worked out and used as its parameter. In this way, errors in body dimensions and weight can be prevented [16]. Moreover, a Biltmore stick was selected to measure standing height, body length, chest depth and hipcross height of the yaks; and, they were weighed by an electronic scale manufactured in Shanghai Yaohua. As for the scale with $1.5m \times 2m$ in its size, it has a weighing range of $0-3t$ and a weighing errorof $\pm 500g$.

2.2 Data Acquisition

Chindu County in Yushu Tibetan Autonomous Prefecture, Qinghai Province, is selected as the research area. Located in the hinterland of Qinghai-Tibet Plateau, Yushu is in southwestern Qinghai, $89°35' - 7°55'E$ and $31°35' - 6°30'N$. Throughout Yushu, its average elevation reaches at least $4,000m$. Annual precipitation and annual average temperature there are about $520mm$ and $0°C$ respectively. Nowadays, its grassland is as large as $0.14 \times 108hm^2$, including $0.11 \times 108hm^2$ of those available [17].

As highly sociable animals, individual yaks that are familiar with each other yearn for forming groups [18]. Among all 25 tested yaks randomly selected, 9 are 1.5 years old (3 males weighed to be $92 \pm 7kg$ and 6 females $95 \pm 6kg$). Besides, there are also 8 $2.5 - year - old$ yaks that are all male and weighed to be $160 \pm 50kg$. As for another 8 adult yaks, they are all female with weight at $195 \pm 30kg$. A herdsman who was familiar with the corresponding yak was asked to stabilize it by holding its horns, so that another people had the chance to photograph it $2 - 3m$ away from it. During photographing, the yak should be in a posture vertical to the center line of the camera to the greatest extent; moreover, the camera was placed in a position that is 2/3 of the yak's standing height. For each yak, at least 3 pictures were taken. With regard to photographic pictures, they have been presented in Figure 2. In the course of photographing, extreme cases were encountered among 3 yaks who behaved badly, including a $2.5 - year - old$ male yak (body arching) and two $1.5 - year - old$ female yaks who leaned backward and formed a rather large included angle with the plane where the camera was placed. In a word, 25 yaks at different age groups were randomly selected from a yak herd to acquire their images by above mentioned means. Then, their weight and body dimensions were measured manually and noted down as well. After the completion of the above experiment, data of weight and body dimensions were further collected for 300 yaks in various age groups by means of manual measurement.

3 Data Processing and Testing

According to the existing public literature, important indexes that reflect growth characters, productivity and genetic characters of yaks consist of their standing height, body length, chest depth, hipcross height and weight. In this study, a person took the responsibility to hold yak horns and ensure correct postures of the yak, while another person measured and recorded relevant parameters. Each parameter was measured three times to give an average value. Subsequently, the yak was pulled onto an electronic scale for weighing. After that, it was pulled again in a photographing area where its image was obtained in a condition of normal stance. In the end, relevant images were processed by a foreground extraction algorithm, a contour extraction algorithm and a measuring point identification algorithm to acquire their body dimensions and weight data. To be specific, measuring points here are defined for visual image measurement, as shown in Figure 1. Considering that front and rear hoofs of a yak may draw close to each other during photographing and the pictures thus taken are all 2-D images, only 4 parameters of standing height, body length, chest depth and hipcross height were obtained here to estimate the weight on this basis.

3.1 Foreground Extraction for Images

A vast majority of yaks have black hairs. However, movement areas of a farm are usually covered with soil. Consequently, it is much likely to see their hair color similar to that of the background. In this consideration, yaks should be herded to a place where its ground color is greatly different from their hair color. Hairs of a yak are coarse, look like pedals and are divided in strands [19], which result in irregular and fuzzy boundaries found during gray analysis on images. To better preserve image boundaries and minimize complexity of further processing, simple linear iterative clustering (Simple linear iterative clustering(SLIC), as shown in Figure 8) is combined with a Soble edge detection operator here to gain the foreground of yak images.

$$D = \sqrt{\left(\frac{d_c}{N_c}\right)^2 + \left(\frac{d_s}{N_s}\right)^2} \tag{1}$$

$$d_c = \sqrt{(L_j - L_i)^2 + (A_j - A_i)^2 + (B_j - B_i)^2} \tag{2}$$

$$d_s = \sqrt{(x_j - x_i)^2 + (y_j - y_i)^2} \tag{3}$$

In Equation (1), dc stands for color distance, ds for space distance and Ns for maximum intra-class space distance. As for Nc that denotes the maximum color distance, it may be substituted by a constant m ranging between 1 and 40 (equal to 10 generally).

3.1.1 Image Pre-processing

From the perspective of computer vision, each pixel of an image should be estimated and determined to be a foreground pixel or a background pixel, which is rather challenging [20]. During photographing, heads of yaks may turn left or right now and them due to site limitations. In this regard, for a yak who faces toward right, its image may be horizontally rotated (switch between left and right) to unify orientations of their heads. Furthermore, image quality is deemed as a fundamental requirement to ensure data accuracy. In the event that images are acquired in natural light, contrast disproportion may be found in them. To solve this problem, histogram equalization should be firstly carried out to improve images' adaptability to the algorithm [21]. After that, an average filtering algorithm was further utilized for denoising [22]. Regarding yak images subjected to preliminary processing, they have been given in Figure 3.

3.1.2 Image Foreground Acquisition Based on SLIC and Sobel

As a typical region segmentation algorithm, superpixel segmentation makes use of clustering methods to fulfill image segmentation based on brightness, colors and texture correlation among pixels. In line with the SLIC algorithm, images are converted from RGB space into LABcolor space; and, local clustering of pixels is executed in 5-D space which is defined by L, A and B values in the LABcolor spacetogether with x and y pixel coordinates [23]. In this way, compact and almost totally homogeneous superpixels are generated effectively. Thanks to its advantages such as high processing speed, high memory efficiency and uniformity with the original image boundary, it has attracted increasingly more attention from researchers [24]. As one of the most important operators in pixelated image edge detection [25], the Sobel edge detection operator consists of two groups of 3×3 matrices, one horizontal and the other vertical. By planar convolution dependent on such matrices, approximate values of brightness differences in horizontal and vertical directions are respectively obtained. In addition, steps of image foreground acquisition based on SLIC and the Sobel edge detection operator are as follows.

Figure 2 Photographic Images

Figure 3 Preprocessed Images

(1) The Sobel operator was utilized to perform planar convolution for original images in Figure 2 and work out their average brightness that served as the threshold; for pixels greater than the threshold, they were deemed as edge pixels, while those below the threshold were non-edge pixels.

(2) Through traversing, each boundary point in the Sobel image was obtained; moreover, the number of total pixels corresponding to all points that were connected to each boundary point was acquired; for connected pixels less than 1% of the total boundary point pixel value, they were eliminated.

(3) SLIC based segmentation was carried out for images that have undergone preliminary processing; in this process, distance of seed points was set at 5 pixels ($N_c = 10$) to solve the SLIC segmentation boundary.

(4) Specific to images obtained in Steps 3 and 2, the Sobel edge detection images were eventually generated, as shown in Figure 4.

(5) The SLIC based image segmentation algorithm was utilized again and distance of clustering centers was defined as 30 pixels ($N_c = 40$); in this way, the SLIC segmentation boundary was acquired.

(6) Regarding images detected in Step 4, if it intersects with the SLIC segmentation boundary obtained in Step 5, then the SLIC boundary of the corresponding clustering center should be supplemented; in addition, a pixel point, which is closest to an image center, of the supplemented boundary should be figured out. Subsequently, extension was conducted based on this point and did not stop until the Sobel image obtained in Step 4 was acquired. As for the final image thus generated, please refer to Figure 5.

(7) In this case, the generated yak boundary image was closed and its central point was set as the starting point to allow filling by feat of a flooding algorithm [26]. As areas where yaks are standing may be eliminated from images obtained in Step 6, color space distance from an edge point of the image obtained based on the flooding algorithm to surrounding pixels was detected. The extension should be iteratively conducted if the space distance is less than the threshold before the acquired foreground pixels remain unchanged.

(8) The obtained image was subjected to expansion and corrosion so that it may become smooth. Eventu-

Figure 4 Sobel Edge Images

Figure 5 Supplemented Sobel Edge Images

Figure 6 Foreground Images

Figure 7 Images with Measuring Points Labeled

ally, the yak image images turn out to be those presented in Figure 6. Regarding operational processes of extracting the yaks' foreground images, it is given in Figure 9.

3.2 Measuring Point Recognition Algorithms

3.2.1 Recognition Algorithm for Standing Height Measuring Points of Yaks

Standing height of a yak refers to distance from its point of withers to the ground. In the case of identifying such a point, its head should be neglected in the first place for the purpose of preventing horns on the head from affecting acquisition of this point. In Figure 7, heads that have been ignored are indicated in yellow. Afterwards, their profile curves of the left upper part to the center were encoded by $24-neighborhood$ chain codes; and, curvature of each point was calculated [27]. In this case, a point with the maximum curvature represents the point of withers of the corresponding yak. During curvature calculations, a triangle may be determined by a contour point in a region where the point of withers is identified and another two points adjacent to it. After lengths of three sides as well as its perimeter P have been acquired for the triangle, the Heron's formula was selected to work out its area denoted as S and the curvature K. When a normal line of measurement is identified, traversing of the lowest points in the left lower part to the center and other lowest points in the right lower part to the center can be performed provided that the yak is standing ordinarily. On this basis, the normal line can be identified. Moreover, such a normal line of measurement may be deemed as the ground, as Line S in black shown in Figure 7. Furthermore, the perpendicular distance from the point of withers to the normal line is the yak's standing height. Regarding lines of standing height, they have been shown by red segments A in Figure 7.

3.2.2 Recognition Algorithm for Body Length Measuring Points of Yaks

Body length of a yak refers to the distance from its punctum ischiacum to its shoulder point. During punctum ischiacum acquisition, contour lines of the yak in the upper right part to the center may be encoded by $8-neighborhood$ chain codes and curvature of each point should be calculated. In this case, the point with the least curvature is the punctum ischiacum of the corresponding yak. As for shoulder point acquisition, head and feet of the yak should be firstly ignored to avoid their influence on shoulder point recognition. Regarding contour lines of yaks with heads and feet removed, they are shown in white in Figure 7. By traversing images of the left lower part to the center, a curve point at the most upperleft end was found within the range. Then, such a curve point was used as the starting point to fulfill searching. Furthermore, traversing of all retrieved points was conducted to locate a point that is the closest to its centre, thepunctum ischiacum. With regard to the body lengths of yaks, they are denoted by orange segments B in Figure 7.

3.2.3 Recognition Algorithm for Chest Depth Measuring Points of Yaks

Chest depth of a yak refers to the height, around its chest, starting from the rear of its scapula. In this paper, chest circumference measuring points of a yak may be gained by identifying lower boundary points of its chest. After the center of the remaining body part with heads and feet eliminated, their lower boundary points were determined to be on the left of its center. Subsequently, a search algorithm was adopted to search the highest point within a range from the lower boundary of this center to the lowest point of its forehoof. Thus, the highest point can be recognized as a lower boundary point of its chest. Furthermore, an intersection between a perpendicular formed by this point and the normal line is the upper boundary point of its chest. As for chest depth recognized by this algorithm, it is represented by pink segments C in Figure 7.

3.2.4 Recognition Algorithm for Hipcross Height Measuring Points of Yaks

Hipcross height of a yak refers to vertical height from its hipcross to the ground. Here, the hipcross point can be identified by recognizing a lower boundary point of its hipcross. The center of the yak was recalculated after its head and feet were eliminated, so that a lower boundary point of its hipcross was determined to be on the right of the above described center. Likewise, a search algorithm was utilized to locate the highest point within a range from the lower boundary of the

Figure 8 SLIC Flow Chart

Figure 9 operational processes of extracting the yaks' foreground images

center to the lowest point of its rear hoof. Again, the highest point is identified as its lower boundary point. Similarly, a perpendicular between this point and the normal line is drawn, so that an intersection of this perpendicular and the upper half of the yak is the upper boundary point of its hipcross. As shown in purple segments D in Figure 7, the hipcross heights are acquired by this algorithm.

3.3 Calculations of Yak Weight

Data fitting was carried out for the collected data based on weka to produce acomputational formula (see Equation 4) for yak weight. In this equation, w stands for weight, h for standing height, s for body length, d for chest depth and t for hipcross height. According to the data acquired, ratios of standing height to body length, standing height to chest depth, standing height to hipcross height, body length to chest depth, body length to hipcross height and chest depth to hipcross height were worked out and used as the essential data. Subsequent to this, proportions of standing height to body length, standing height to chest depth, standing height to hipcross height, body length to chest depth, body length to hipcross height and chest depth tohipcross height were calculated. Respectively, such proportions were compared with the essential data one by one to figure out relevant errors and define K data with the least errors. In this paper, K was equal to 5. Thus, body measurement data of 5 yaks were generated and averaged. After that, data obtained through calculations were substituted into Equation (4) to work out their weight.

4 Results and Discussions

4.1 Algorithm Stability Analysis

Three stances have been defined for yaks, as given in Table 3.

With the goal of detecting algorithm adaptibility, measuring points of the same yak in different stances were extracted. These extracted measuring points on body sizes of yaks in diverse stances are revealed in Figure 10. To be specific, measuring points of the yak in Stance 1 are presented in Figure 10a, while Figure 10b and Figure 10c respectively indicate measuring points obtained in Stances 2 and 3. It has been proven by relevant results that this algorithm has the potential to accurately recognize measuring points on bodies of yaks. As signified by testing totally 103 yak pictures collected, foregrounds can be extracted from 98 yak pictures by virtue of such an algorithm, generating a recognition accuracy of 95.15%. Regarding 95 images with foregrounds identified, measuring points can be accurately labeled; in this case, the recognition accuracy turns out to be 92.23%. It has been found from experimental results that such an algorithm is preferably adaptable and performs accurately and robustly in extracting measuring points in various stances.

Figure 10 Measuring Point Labeling Images

Table 4 Data of Randomly-selected 10 Yaks

Serial No	Age	Gender (F/M)	Stance
1	1.5	M	1
2	1.5	M	2
3	1.5	F	1
4	1.5	F	3
5	2.5	M	1
6	2.5	M	2
7	2.5	M	3
8	Adult	F	1
9	Adult	F	2
10	Adult	F	3

4.2 Analysis on Body Measurement Detection Accuracy and Results

Body measurement data of 10 male or female yaks in diverse age groups (see Table 4) were selected to generate measurement results by virtue of the above algorithm. These results have been given in Figure 11.

In conformity with data analysis, mean errors between the calculated values and the measured values of standing height, body length, chest depth and hipcross height are respectively 0.37%, 1.428%, 2.009% and 2.774% as far as Stance 1 is concerned. The reason why such errors for chest depth and hipcross height are rather large is that both chest depth and hairs in the lower part of the hipcross are exclusive during calculations of them by a Biltmore stick; and, although preliminary image processing has been performed by the proposed method, it fails to utterly remove hairs below the chest and on the lower part of the hipcross. In terms of Stance 2, mean errors between the calculated value and the measured value of standing height, body length, chest depth and hipcross height are 0.534%, 2.264%, 2.68% and 3.255% respectively. In addition, all relevant data are reduced. The reasons for large errors found in body length, chest depth and hipcross height is that center line of the yak's back forms a rather great included angle with the center line of the camera. Due to this included angle, impressions of the body length, the chestdepth and the hipcross height are cut down in their images. As regards Stance 3,

Table 3 Definitions of Yaks' 3 Stances

Serial No	Description
Stance 1	Yak's back centerline is perpendicular to the centerline of camera; the camera height is 2/3 of yak.
Stance 2	Yak's back centerline is at least 70° from the centerline of camera; the camera height is 2/3 of yak.
Stance 3	Yak's back centerline is at least 70° from the centerline of camera; the yak's head is bent to one side; the camera height is 2/3 of yak.

Figure 11 Body Measurement Data Analysis for Yaks in Different Age Groups

a mean error of 0.742% is generated by the calculated value and the measured value of standing height; however, all calculated and measured values are comparatively small, because heads of the yaks tilt during photographing, which leads to a slight decline of their points of withers. For mean errors between the calculated values and the measured values of body length, chest depth and hipcross height, they turn out to be 3.32%, 3.531% and 3.957% respectively. Again, all such data decrease. The reason why mean errors of body length, chest depth and hipcross height are rather high is similar to that for Stance 2. As demonstrated by measurement results of the same yak in three different stances, the calculated value of standing height is slightly deviated from its measured value in an extreme stance, while data of its body length, chest depth and hipcross height decline to an extent greater than that of their measured values. By averaging data obtained by repeated measurements, better results can be generated.

4.3 Weight Detection Accuracy and Result Analysis

Specific to 300 items of yak related data that are manually acquired, univariateand multivariate regressions are performed to predict the weight by means of linear regression, Gaussian process, neural network and support vector machine, etc. Relevant model prediction details have been given in Tables 5 and 6. According to corresponding results, high correlation coefficients are generated if their weight are obtained by image processing. This signifies that parameters gained through image processing can be used for modeling. During univariate analysis, chest depth exerts a more significant influence on weight; in the course of multivariate analysis, the linear regression method with comparatively high correlation coefficients and low errors produced features, as for model validation, the least standard deviation ($9.2779kg$) and the least mean error (6.24%). In the end, data validation results for 25 yaks that are divided into different age groups are acquired and presented in Tables 7 and 8.

4.4 Discussions

In this section, performance and applications of body measurement algorithms for yaks are assessed.

Table 8 Mean Error Detection Results Based on Data of 25 Yaks

Items	Max. Error	Min. Error	Mean Error
Standing Height	10.90%	0.03%	1.95%
Body Length	12.10%	1.03%	3.11%
Chest Depth	10.20%	1.15%	4.91%
Hipcross Height	9.09%	0.84%	3.35%
Weight	18.90%	1.31%	7.79%

In terms of such algorithms, a method proposed by Lina Zhang [5]specific to small tailed han sheep is featured with being simple, convenient and independent of any particularly established construction. In comparison with another method raised by Tillett [3], that is to acquire morphological data of swine from 3-D images, the former can be much simpler. However, errors are incurred in this paper because of the failure in recognizing sufficiently accurate measuring points. If compared with the method developed by Larios [28], the proposed approach here does not require sensors and can be also embedded in portable devices such as a mobile phone. Yaks which are huge and wild cannot be treated like ordinary domestic animals. In this context, 3-D measurement or sensor-based measurement may be applied. It is also demonstrated by research findings that the image analysis based yak body measurement algorithm is feasible. In place of manual measurement or other methods with a low automation level, the proposed algorithm has the potential to improve herd management efficiency.

5 Edge Computing Enable Smart Stockfarming - A Prospect

In this paper, body dimensions and weight of yaks in the three river source region are acquired by means of machine vision and data mining. Moreover, it is feasible that such two methods are combined to assist yak feeders in gaining yak weight rapidly, effectively, practically and conveniently. In addition, the proposed algorithm can be also transplanted into a mobile device to investigate growth conditions of yaks, which is also deemed as a reasonable solution. Considering that yaks are dramatically wild, it is extremely dangerous to perform body measurement on them. However, not only can the proposed algorithm make it less dangerous to weigh yaks on the premise of fewer workers are required, but also can it be used foranalytical and statistical investigations on yak related data

$$w = 1.0621 \times h + 0.7202 \times s + 4.6187 \times d + 1.0350 \times t - 398.6303 \quad (4)$$

Table 5 Univariate Regression Model Based Prediction

Methods	Prediction Models	Correlation Coefficients	Mean Absolute Errors
Gaussian Process	w-h	0.9134	$35.6980kg$
	w-s	0.8788	$34.2904kg$
	w-x	0.9510	$33.5746kg$
	w-t	0.9002	$35.9175kg$
Linear Regression	w-h	0.9242	$12.7891kg$
	w-s	0.8843	$17.6061kg$
	w-x	0.9557	$11.0046kg$
	w-t	0.9109	$15.1768kg$
Neural Network	w-h	0.9317	$14.8992kg$
	w-s	0.8843	$17.6061kg$
	w-x	0.9411	$13.0996kg$
	w-t	0.9040	$17.4134kg$
Support Vector Machine	w-h	0.9260	$11.6628kg$
	w-s	0.8837	$17.1875kg$
	w-x	0.9547	$10.6619kg$
	w-t	0.9061	$15.1020kg$

from the long run. This is significantly beneficial for body dimension and weight detection in a large-sized farm. Except body measurement error rate reduction and estimation sensitivity improvement, the proposed method also plays a part of preventing and diagnosing health issues caused by feeding, monitoring yaks raised in large yak farms and thus improving productivity.

The evolution of the hydrological-ecological system in the Three River Source Region is related to the s-trategic security of China's water resources. The study and analysis of the changes in the ecological environment of the Three River Source Region is conducive to better protection of the Three River Source Region ecosystem. For a long time, yak breeding has a great impact on Three River Source Region ecosystem. The research method of this article is used to monitor the growth status of yak by RFID measuring instrument [29] and video monitoring methods. Using cloud edge computing [30] method to get Yak's growth state in time while keeping network security [31–33] through distributed router [34]. Through the above-mentioned modern means, ensure the real-time transmission, analysis and processing of yak's growth evolution monitoring data in Three River Source Region [35]. It is of great significance to the ecological environment protection in the Three River Source Region.

At present, with the establishment of Smart Ecological Animal Husbandry Information Cloud Platform in Three River Source Region [36], the weight of yak can be estimated quickly by yak photos if the platform is recommended by this method when herdsmen use the platform, which will be of great help to herders who breed yaks.

6 Conclusions

Specific tests through experiments show that:

(1) Regarding images collected in a scene, the proposed algorithm is capable of generating split images with preferable edge information and effectively extracting contour information of yaks.

(2) In experiments of extracting measuring points on images of yaks that are in diverse stance, the proposed algorithm is demonstrated to be preferably adaptable.

(3) Testing results indicate that averaging the values that are obtained through repeated measurements may enhance accuracy of the measurement system.

(4) Errors may be reduced to the greatest extent by holding the camera horizontally and making the plane where the camera is placed parallel to that where the yak is standing.

(5) In accordance with yak weight prediction results, parameters generated by image processing can be used to monitor growth situations of yaks.

(6) Being transplantable, the proposed algorithm may be embedded in a portable device to estimate body dimensions and weight of yaks.

As proven by experimental results, the proposed method can be utilized to effectively obtain body dimensions and weight of yaks without contacting them, which provides body-measurement-based yak assessment, breeding and feeding guides in a welfare agriculture management pattern.

Abbreviations

SLIC:Simple linear iterative clustering;

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Author's contributions

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Table 6 Multivariate Regression Model Based Prediction

Methods	Prediction Model	Correlation Coefficients	Mean Absolute Error
Gaussian Process		0.8667	$32.4920kg$
Linear Regression	$w = 1.0621 \times h + 0.7202 \times s + 4.6187 \times x + 1.0350 \times t - 398.6303$	0.9670	$9.2779kg$
Eural Network		0.9298	$11.2226kg$
Support Vector Machine		0.8661	$15.4701kg$

Table 7 Data Validation Results of 25 Yaks in Different Age Groups

Methods	$1.5 - year - old$ Male Yaks	$1.5 - year - old$ Female Yaks	$2.5 - year - old$ Male Yaks	Female Yaks in Adulthood
Quantity	4	6	7	8
Standing Height Error	4.01%	2.32%	2.50%	2.57%
Chest Depth Error	4.79%	5.58%	3.82%	6.04%
Body Length Error	2.86%	2.32%	5.38%	5.03%
Hipcross Height Error	6.23%	6.23%	4.17%	2.02%
Weight Error	4.27%	9.34%	10.46%	7.30%

Availability of data and materials
The authors declare that all the data and materials in this manuscript are available from the author.

Competing interests
The authors declare that they have no competing interests.

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Figures

Figure 1

Description for Yak Body Measurement Points.

Figure 2

Photographic Images

Figure 3

Preprocessed Images

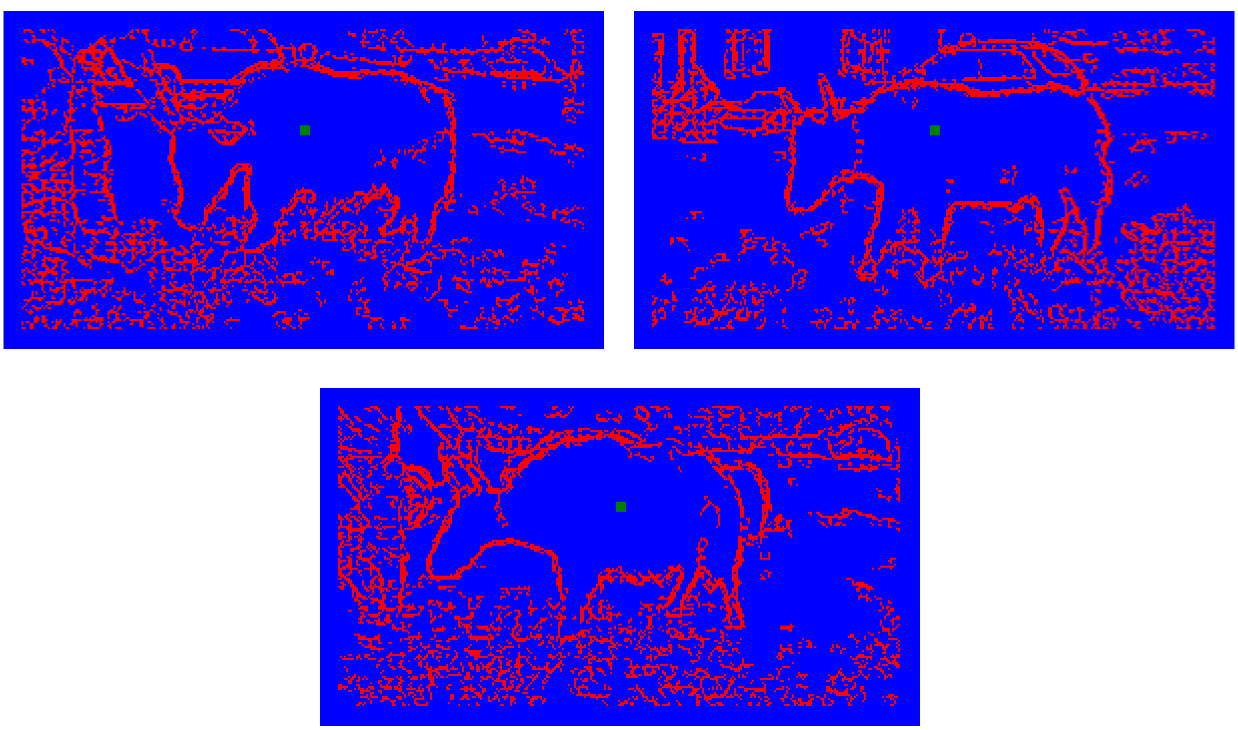

Figure 4

Sobel Edge Images

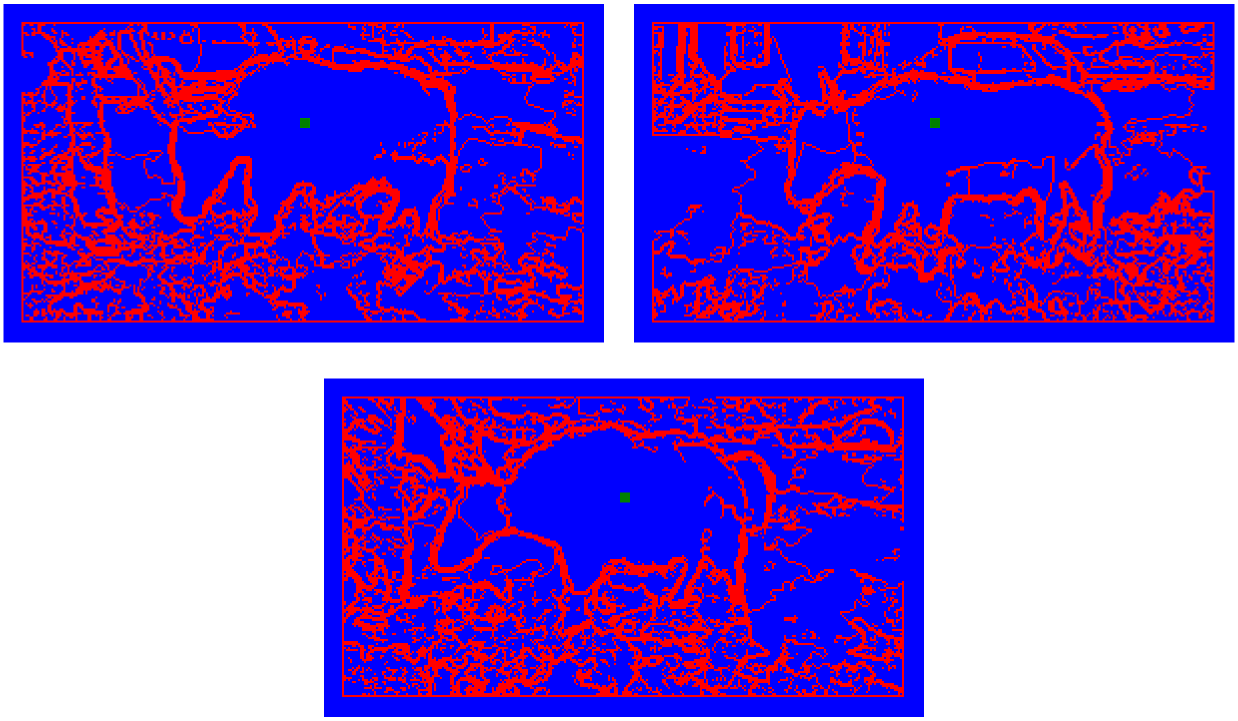

Figure 5

Supplemented Sobel Edge Images

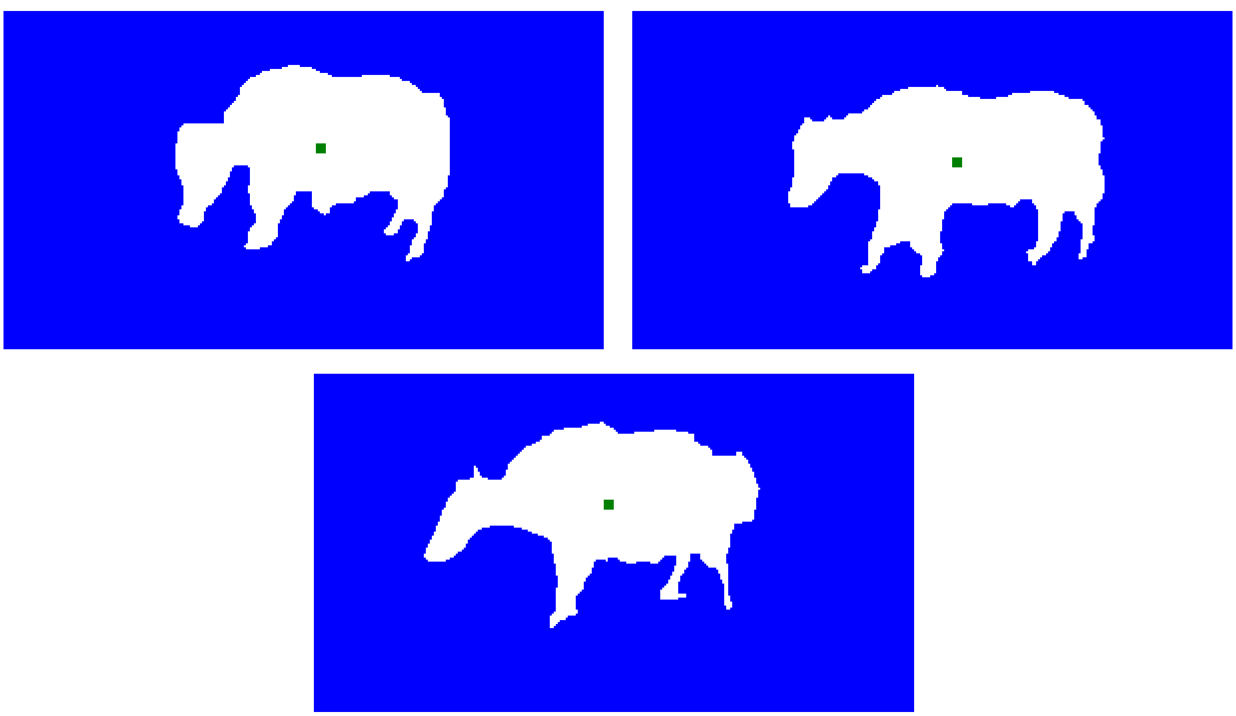

Figure 6

Foreground Images

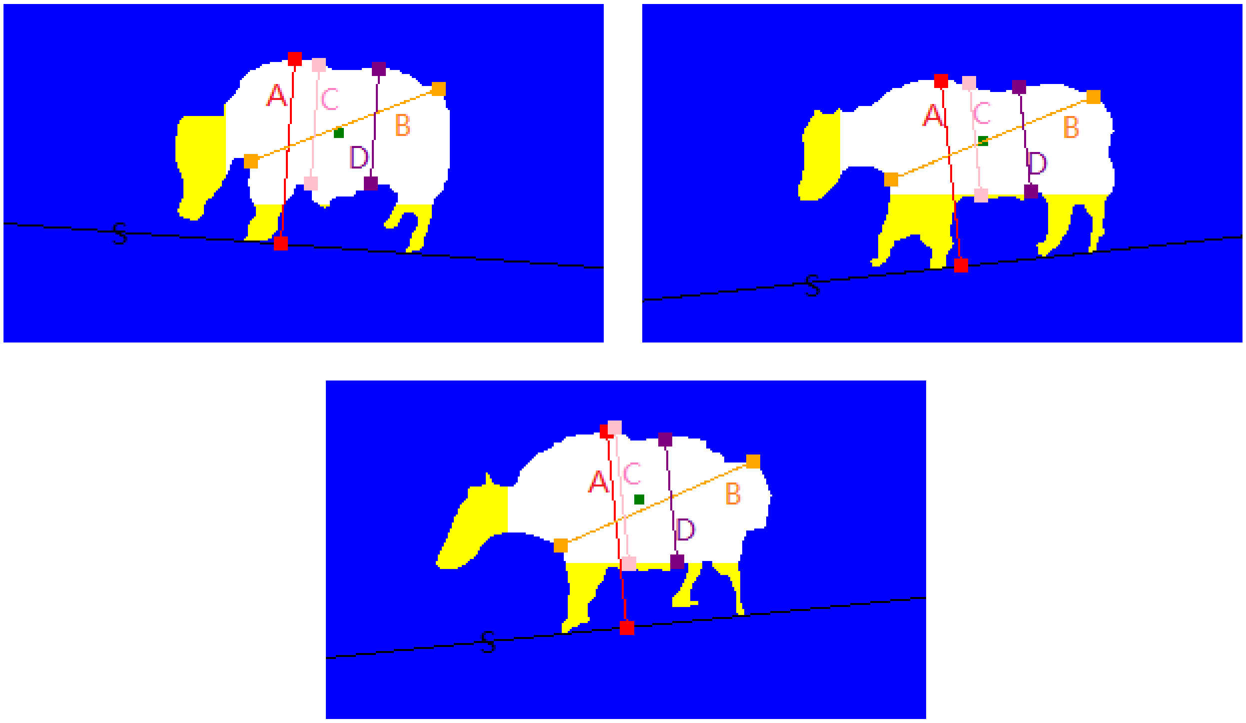

Figure 7

Images with Measuring Points Labeled

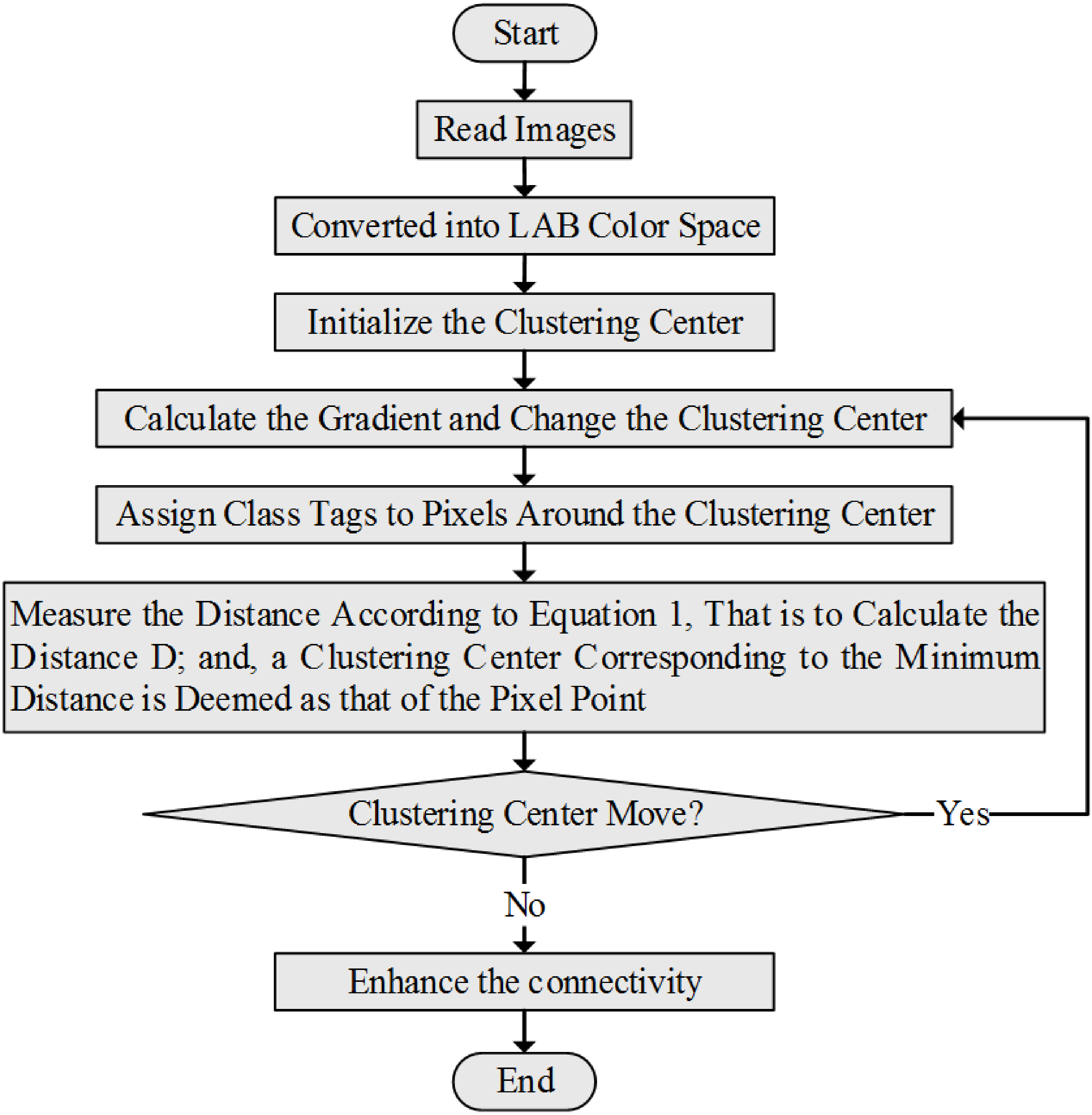

Figure 8

SLIC Flow Chart

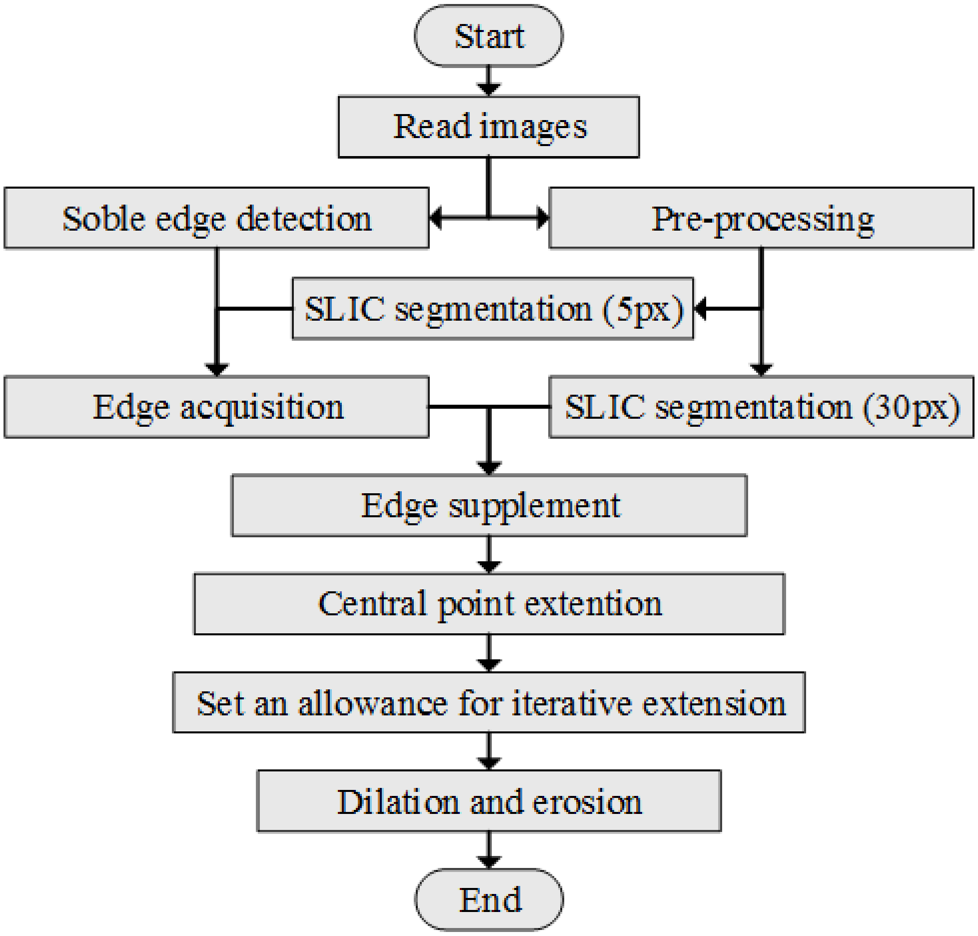

Figure 9

Operational processes of extracting the yaks' foreground images

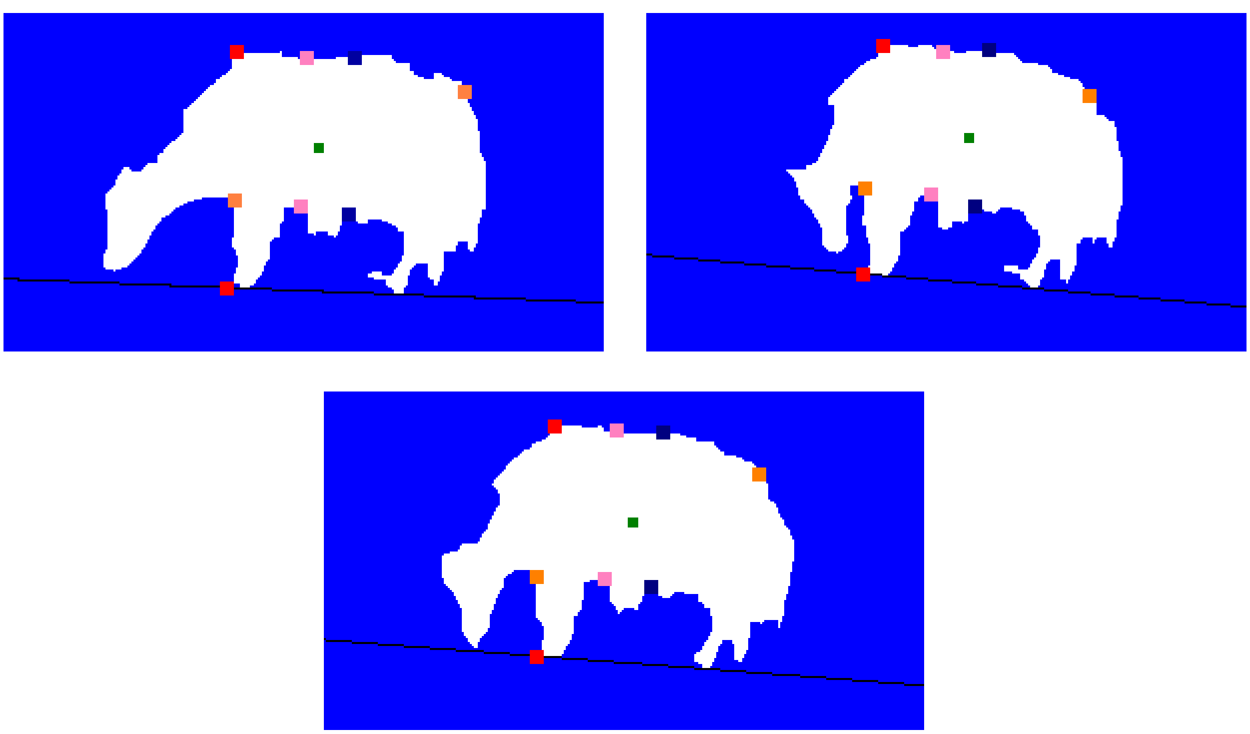

Figure 10

Measuring Point Labeling Images

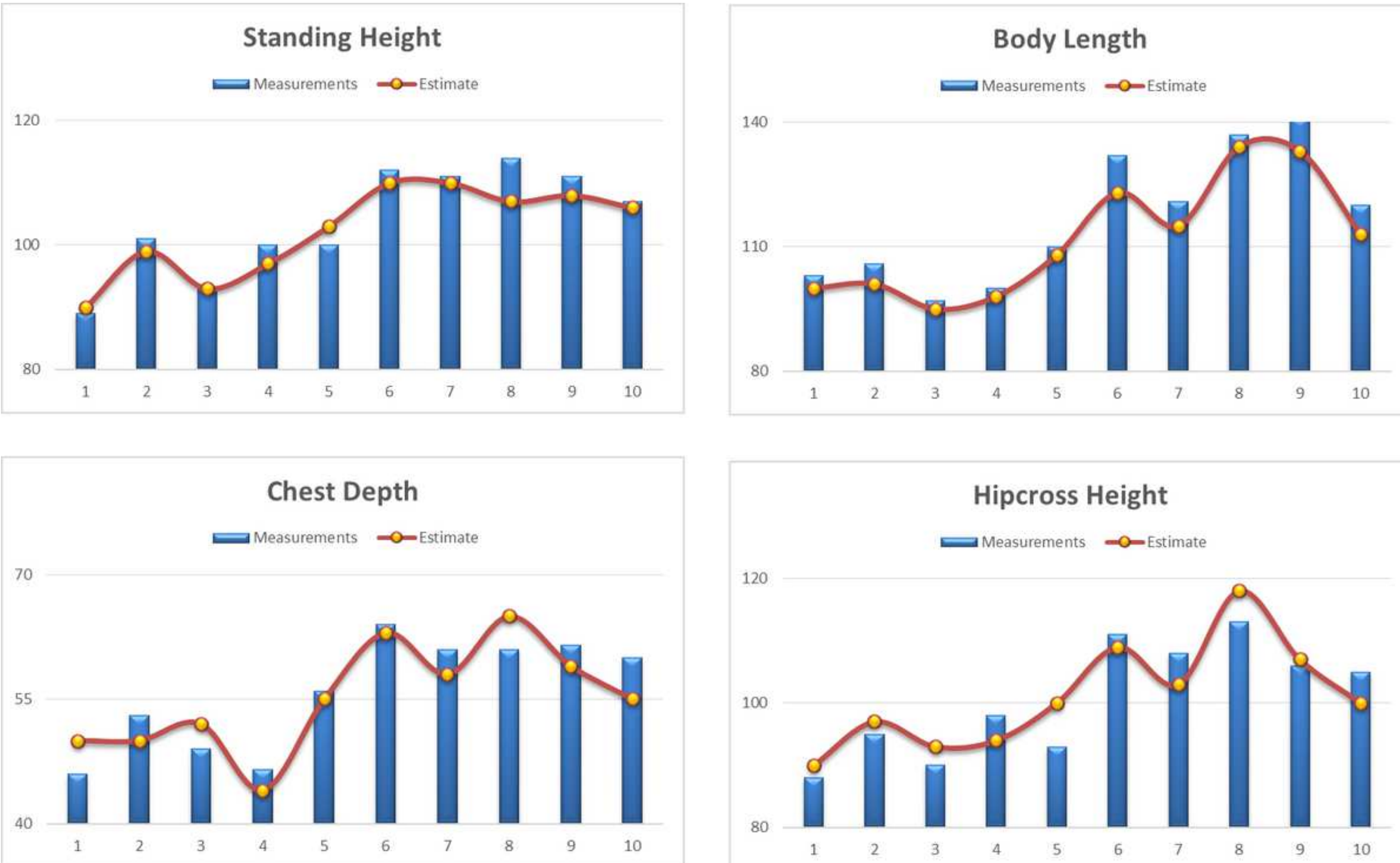

Figure 11

Body Measurement Data Analysis for Yaks in Different Age Groups