# Estimation of Pig Weight by Machine Vision: A Review

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**Abstract.** In pig production, food conversion ratio and profit can be evaluated by real time detection of pig live weight. Traditional pig weight detections usually require direct contact with pigs, which are limited by its low efficiency and result in a lot of stresses even to death. The non-contact detection of pig body weight has become a challenge in pig production for decades. Digital image analysis and machine vision method enable the real time estimation of pig live weight by detecting pig critical body dimensions without any contact. This article elucidated the advantages and limitations of each detection method of pig body weight by comparing the system framework and estimation models. The research trends of contactless pig weight estimation were analyzed as well.

**Keywords:** Pig, weight, machine vision, estimation, reviews

## 1 Introduction

Weight is an important index in pig rearing. Pig's daily gain and nutritional status can be evaluated immediately through getting pig's weight timely [1]. Even the feed utilization efficiency can be detected by combined with automatic feeder [2].Then pigs in good or bad nutrient status could be raised separately to meet uniform marketing weight standard.

In traditional weight measurements, pigs need to be moved to weighing devices such like mechanical scale and electronic balance. The whole process is time consuming and laborious, it often requires at least two stockmen to spend 3-5 minutes for each pig [3]. This process brings lot stress to pig and even leads to sudden death; feed intake is going down on the day of weighing compared to before and after the weigh day [4]. Recent years, some manufacturers added weighing sensors inside the automatic feeder to weigh and record pig weight real-time. Most of these apparatuses are expensive and prone to erosion by sewage. In addition, they need to remold original piggery.

Due to numerous problems of contact weight measurement, the non-contact measurement attracted attentions to measure or estimate pig weight. Early in 1988, digital image analysis were proposed to have about 90 kinds of potential applications in stock farming, which can be used to estimate pig weight [5]. Many researches have proven that there is being significant correlation between animal body sizes and their body weight. Through image analysis and machine vision technology, key sizes or back area of pig could be obtained. Combining with the relation model of body sizes and body weight, pig live weight can be estimated accurately. The measurement technique based on machine vision presents many merits, such as non-contact, fast and labor saving. The non-contact measurement has not been widely applied in practical engineering, although it was researched for decades. In this article, the application of machine vision technique in estimating pig weight has been reviewed from two respects of system frame work and prediction model according to the form of machine vision.

## 2 System framework

A complete machine vision system mainly includes following aspects: light source, lens, camera, image capture card, image processing platform, machine vision software, I/O (Input/ Output) devices and execution control mechanism. The control mechanism is not needed in pig weight estimation system, and the only output is pig weight information. Thus this chapter summaries as the following aspects: camera location, light source and image trigger method.

### 2.1 Camera location

In order to get pig body sizes as many as possible, cameras were not only set at the top of pigs, but also at the side of pigs. The camera on the top of pig could get the pig back area and the one at the side of pig is set to get pig's body height [6]. To reduce the number of cameras, pig was put in a weight cage, and a mirror was installed on the top canted 45 degree. Camera was fixed in the flank of pig. Consequently pig's black area and its body height could be attained from one shoot [7]. There are still some disadvantages. Cameras are prone to contaminated by smudginess, and the pig being measured is possibly covered by other pigs.

For the protection of cameras, most researchers only set up the camera on the top of pig. The image from top view can provide the pig body width and body length rather than the pig body height. Binocular vision technology could get depth information with two cameras fixed on the top of pig through image matching. The pig body height information could be figured out by 3d coordinates of points taken form the binocular vision [8].

The location of camera should be convenient for image capture and analysis, so that image with only one pig with straight body and static could be taken. Camera is commonly set up at the top of the feeding station or drinker, because pig's body is straight and motionless when it is drinking or eating. If only one pig is allowed to enter into feeding station, which is too narrow for pig to turn round or bend. High quality images could be attained when camera was put on the top of feeding station [9].

Similarly, cameras were also fastened upper the drinker for the high quality image [10]. Most time pig's body will be straight when it is drinking. But when the temperature is high in summer, pig will scramble for the drinker, and like to lie in the drinking area. This brings a lot of troubles for image collection and pig contour extraction.

With the development of digital camera, shutter speed advance greatly and reduce the requirement for pig state of motion. Even fast moving pig can be snapped clearly. A gallery with a camera on the top is built to let pigs go through [11, 12]. System is always running to detect the appearance of pig and catch appropriate images. But the shortcoming of this method is that pig tend to remain and explore in the aisle, which will influence image capture. And this method need to remold pig house which increase the investment and difficulty of system implementation.

On the whole, when pig house is already built, putting the camera on the top of feeder or drinker area is more practical way, automatic feeding station that allowed only one pig enter one time is the idealist way.

### 2.2 Light source

Light source is the most essential part of machine vision system. A good light environment not only enhances the contract between foreground and background, and simplify image processing algorithm, but also increases system speed and robustness. In the pig body size detection and body estimation system, light source also plays a very important role.

Light is scarcely taken into account in the early research. Only the relationship between illumination intensity and binaryzation threshold is discussed briefly. Two filament lamps or two strip fluorescent tubes for illumination were used in most researches. In consideration of field application the semi-closed structure was used, where only one pig is allowed to go through or entrance. In the semi-closed structure, the sun light is warded off to avoid impacting pig contour extraction, and the background was painted to black artificially to enhance the contrast.

In a real house the background is much complex. The illumination of image acquisition area is inhomogeneous, because most pig houses have window for day lighting. This brings lots of challenges to image analysis. Many researchers used automatic exposure to response the change and inhomogeneous of environment light, but this seems inadequate. It is easy to get the wrong part when extracting pig image, with the present of water spots or sunshine illuminate area in the field of view. It is inevitable for pigs to smear dirt whose color is close to the ground. From the top view, the dirt located at pig outlines will bring errors to contour extraction.

Different color lights were tested to simplify pig image analysis, one machine vision system use a projector as light source and a clearer pig image suitable for image analysis was obtained when using a red slide film printed with yellow mesh lines fixed before projector [13]. This resulted from the higher reflection ability of red light compared to that of the blue and green light when the color of pig body is present as white and slightly red.

A systemic study of light for pig weight estimation system was made. Several light sources' characteristics and price were compared, such as fluorescent lamp, halogen lamp, LED (Light Emitting Diode). The strip fluorescent lamp was suggested to use for uniform light. Limited by the piggery condition, the only location of light source is the top of pigs. Three different color filters were used to transform white light of fluorescent lamp to three monochromatic lights (red, green and blue) as light source, then diversity of quality of image were analyzed. Red light is the best among three kinds of lights. Slant red light is recommended in practical to help the pig extraction [14].

### 2.3. Image trigger method

After camera is installed, system needs signal to trigger snap image. Some systems have no trigger hardware, and systems are processing image all the time no matter whether there is a pig or not in the view. Hot point and cross hair method were used to monitor some points gray value to judge whether pig is appeared in image [15, 16]. And the system is always in a state of computing and waiting, leading to a low efficiency. A new method was invented to snap image [17], where a flow switch installed in water line is used as a trigger. The flow switch change state when pig is drinking, then the connected camera is triggered to capture image. This method does not need system detect and process image all the time, and has higher efficiency. Combining with RFID (radio frequency identification devices) reader, the designated pig can be snapped. But this method needs to remodel water line with the increase of system cost.

Optoelectronic switch was used to detect the appearance of cow [18, 19], with the image snap controlled by MCU (Microprogrammed Control Unit). Sensor and peripheral circuit are included in this methods, resulting in the increase of system complexity and reduction of stability.

RFID reader is a good way to control snapshot. A RFID reader is fastened near the feeder or drinker. When pig is feeding or drinking, RFID reader fetch the ID of pig, then send a break to system to take a shoot. This way combines with pig identification and needs no more additional equipment to achieve image trigger snap conveniently.

## 3 Estimation Model

It is found that some pig's size have fine correlation relation with pig's weight. Studies on the selection of measurements parameters are necessary to estimate the pig's weight accurately.

The pig's weight was intended to be calculated by pig volume multiplying the pig's density. But pig's shape is irregular and difficult to be measured. In the previous research, pig was simplified to a cylinder and a cone. Then body length and chest circumference were used to compute volume to build relevant model with pig weight and the average relative error is about 2.8% [20]. However chest circumference can't be obtained by image technology, so this method is not practical. There is an obvious error in the estimation of pig's volume, because it's very hard to define regular shape to match every body part accurately.

The relationship of two dimensional area and one dimensional body measurements with weight were built respectively. Due to the structure of piggery, camera have to be put on the top of pig to catch the pig's back image for body size. Camera coordinate system could be built through calibration which helps the transform of image area to real area, and image length to real length. The relation of average number of pixel of pig back area with body weight was established. The relation varied among different breeds. The average error of estimation weight is below 5%. Within the range of 60-90kg weight, some breeds' error are under 2% [9]. A few body measurements were used to establish relationships with weight. The better model among those relationships is power equation between pig back area and weight, whose estimation error was less than 3.7% [15]. Those relationships built between number of pig back pixel and weight seems not universal. If any factors such as camera height and resolution ratio are changed, the model is no longer suitable and need to be rebuilt. If pig back area and body size are real dimensions, so that the model is not influenced by system configuration.

Pig height information is prerequisite for transform image area to real area. The object's coordinates obtained by single camera cannot compute the height information without other devices. Pig is assumed as a cylinder with certain radius (*r*) and height (of the ground, *h*). The values of *h* and *r* are gained from a lookup table of ASAE [16]. The model using back area (A4) without ear and neck with weight is as following.

$$\mathrm{W} = -15.56 + 411.3A_4 \tag{1}$$

If each pig's model is corrected by 75 days' weight, estimation error and the relative error are within 1kg and 1.25%, respectively. But this method cannot be used in practical application obviously, owing to the need of the lookout table.

A calibration scale was put on 0.5m height to get pig body size and area information [3]. This method doesn't calibrate the camera, so when the pig's height does not equal to 0.5m, pig's width and length will be incorrect.

A technology similar to the structured light was used to measure pig height [10]. A slide projector was fixed to the ceiling above the drinker to project shadow lines of lattice pattern. The difference in pixel of shadow line length between on the shoulder of the pig and on the floor was measured, then pig height was obtained using a geometric relationship between pixel difference and height. The mathematical model is established as followed.

$$\mathrm{W} = 5.68 \times 10^{-4}A^{1.16}H^{0.522} \tag{2}$$

Where W is the pig weight; A is the pig back area without pig ear; and H is the pig height. Twelve pigs were estimated for five times between 81 to 98 days old, the relative error is 2.1%. But this method is easy to be influenced by piggery light environment.

The distance from the pig's back to camera was recorded manually for every photo to get pig body height. And a ruler was put on the pig back to get the real size [21]. Using Matrox image process software to extract pig's size. Back area was found having well relevant (*r*=0.96) with weight compared to several body sizes. Body width also has better relevance (*r*=0.95). The best body measurement was extracted by the image process to build mathematical model. In order to estimate pig weight, the model was verified to be appropriate by regression analysis. The relative error is 6%. Artificial neural network was used to make model with 3% relative error later.

The pig's body size detect and weight estimation system was designed by Fu Weisen. The coordinates of key point in two pictures were found by image matching, and three-dimensional space coordinates could be computed through stereo vision principle. The relative error of pig's body size is around 1%. Eleven body measurements including pig length, width and height were used to build an estimation model through principal component analysis. Field experiment showed the average relative error of pig estimation weight is 0.77% [8], which indicated a certain practical value.

Back area has higher correlation coefficient with pig weight than body size, and the prediction model of area is also better than body size's model. It was found that both central and vertical projection area have very high dependency with weight, but the former is better than later [10]. Central projection area is the area of image range of pig projection to camera CCD sensor. Vertical projection area is the pig projection area without height influence, and it is a real two dimensional area. The central projection area have positive correlation with height, and it could be taken as a three dimensional body measurement. This also could explain why central projection area has better correlation with weight than vertical projection area.

In extraction of area, many researches demonstrated that pig's head, ear and tail have large range of motion and influence on the stability of area extraction. It should be removed out of the statistics. It is found that body length have higher correlation with weight, partly because the magnitude of length is larger than width and changes significantly over time. In contrast, width and height change little over time. But in actual measurement process, pig is always moving especially its head, neck and fore hoof. The uncertainty get high when the pig's body height and body width are tested which lower the correlation with weight. Therefore, parameters which are little influenced by the pig motion should be chosen. In addition, it is crucial to keep pig stand with a straight and head rising posture when it is snapped.

Varied breeds need different estimation models. Estimation model is affected rarely by the weight interval or genders. In Schofield`s linear model, every pig has different intercept. The manual measurement weight was used to calibrate the model, with the drop of the relative error from 5% to 1.25% [16].

## 5 Summary

Machine vision technology has been widely used in the industry, but the applications in agriculture are mainly concentrated in the field of plant and food classification such as nondestructive testing. Noncontact testing of live animals is limited by many factors such as harsh environment and poor light condition, the estimation system could accommodate the environment of pig house and run stably for a long time. The image analysis algorithm should adapt to uneven illumination environment to get a right pig contour. Due to the moving nature of animals, it's a great challenge to snap a straight and head raised pig's image, the location of camera and image trigger mode can deal with this challenge. In the same time, how the estimation system combine with auto feeder and maximizing precision and repeatability should be considered as well.

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