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A portable and automatic Xtion-based measurement system for pig body size

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ABSTRACT

Body measurement plays an important role in animal breeding and production. In this paper, we develop a novel portable and automatic measurement system for pig body size. Firstly, we utilize two depth cameras to capture the point clouds of the scene with a pig from two viewpoints and implement the registration of the obtained point clouds. Secondly, we resort to Random Sample Consensus (RANSAC) to remove the background point cloud and extract the foreground pig point cloud with a Euclidean clustering. Finally, body measurement is conducted via pose normalization and morphological constraints on pig cloud. We evaluate the proposed system on 20 sets of the scenes with a pig in a commercial pig farm. Experimental results show that the pig object extraction algorithm achieves good performance. The average relative errors for body width, hip width, and body height are 10.30%, 5.87% and 7.01% respectively, which demonstrates the efficacy of the proposed system.

1. Introduction

Over recent decades, the use of conventional livestock breeding techniques plays a major role in increasing livestock production (Leaky et al., 2009; Thornton, 2010; Veerkamp et al., 2002). Taking accurate body measurement is one of the keys in the breeding plans of the livestock for the correlation with production traits (Pallottino et al., 2015). Besides, body measurement plays an important role in indicating leg weakness (Van Steenbergen, 1989), the value of a carcass (Horgan et al., 1995) and general health of the animal (Coffey et al., 1999). Moreover, the measurements from the livestock are usually closely related to the weight which is significant to the process of real production (Pope and Moore, 2002). Therefore, it is imperative to develop an efficient technology to obtain the body measurements for the livestock.

Traditionally, livestock body measurements including body length, body height, hip width and any other morphological measurement is carried out manually, *e.g.*, the morphological measurement can be conducted with measuring tape, measuring stick and any other traditional measuring tools by the feeder. However, with the number of livestock increasing, this traditional method become ineffective, time-consuming and even stressful to the animals. To overcome many shortcomings of the traditional measuring method, digital imaging technologies have been proposed for several livestock species including pigs (White et al., 2004) and cows (Ozkaya, 2012; Tasdemir et al., 2011). However, the existing digital imaging methods still have a certain limitation, *e.g.*, the change of illumination, shadow and background noises will affect the correctness of segmentation, which may lead to the wrong estimated results (Shi et al., 2016).

Nowadays, the advancement of computer and photoelectric technology offer an alternative way to estimate the measurement. 3D image processing technology was successfully used in the estimation of livestock body measurements. Stereo vision methods have been introduced to measure livestock in three dimensions (3-D). Wu et al. (2004) performed experiments using a stereo imaging system with multiple cameras to obtain the 3D image of live pigs. However, the stereo vision system is sensitive to the visible lighting conditions and difficult to implement. 3D cameras like Time-of-Flight (TOF) cameras were introduced to acquire the livestock body measurements successfully (Weber et al., 2014; Salau et al., 2014). However, the TOF camera is sensitive to motion artefacts. Depth cameras using structured infrared-light (IR) technology, such as the Microsoft Kinect V1 or the ASUS Xtion Pro, have been introduced to measure the body size of the livestock. The depth cameras are less susceptible to motion artefacts and their cost is low compared with other visual systems. In cows, the systems based on multi-Kinect cameras were used to automatic evaluate functional traits of cows (Salau et al., 2016, 2017). In pigs, Guo et al. (2014, 2017a,b) has proposed system prototype for body measurements. However, the study mentioned above is incapable of automatic measurement of the pig body size.

In view of the above, the objective of this paper was to study: (1) method of live livestock 3d point clouds acquisition including scene registration and pig segmentation; (2) method of automatic livestock

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Fig. 1. Photo of the pig and the portable measurement system operated by the tester in the pig farm. The photo was taken in the daytime.

body measurements estimation (3) the validity of the method in this paper to estimate the live pig body size.

2. Experimental setup

In this study, we choose Xtion pro as point cloud acquisition equipment. The Xtion sensor used in our experiments consists of an infrared laser projector in combination with two optical sensors for RGB imaging and depth sensing (Gonzalez-Jorge et al., 2013). Because of the capacity to acquire 3D point cloud, the sensor has been used in many computer vision systems (Mortensen et al., 2016). To avoid the possible affect of sunlight to the quality of 3D point cloud, we conduct the measurement experiments in closed environments like a pig house. We observe that the 3D point cloud acquired is more liable to segment, and it is robust to the visible lighting conditions.

As illustrated in Fig. 1, the system is composed of a portable metal stand, a laptop, a mobile laptop desk and two Xtion cameras. The two Xtions are mounted to a metal stand. The distance and angle of the two Xtions can also be adjusted, and the area covered by the camera is about 4 square meters when the distance from the camera to the ground is about 1.5 meter. The laptop (with an Intel i7 processor and 16 GB RAM and a CUDA-enabled GPU Nvidia GTX 580 M) is fixed at the operator using a mobile laptop desk. The laptop supplies the energy for the two Xtions which are connected with the PC using USB cable. The frame rate is about 4 FPS.

3. Methodology

We firstly set up the depth camera to make sure the field of view of the camera to cover the pig completely, and then acquire the scene point clouds including the pig. The scene point cloud is the input for the proposed system. Note that to make sure that the system works well, during data acquisition, the tester should guarantee that there are no other objects between the operator and the target pig and no pigs are touching.

After registration of two point clouds collected from the two depth sensors, the proposed system is going to proceed 3 steps: (1) extracting the pig cloud from the pig farm using Euclidean clustering extraction and random sample consensus, (2) conducting pose normalization using a PCA algorithm based on the ground normal vector, and (3) using morphological constraints of pig itself to calculate the body size. The algorithmic flow and sample results for each step of the process is illustrated in Fig. 2. The algorithm is developed and executed in the VC++ programming environment with the Point Cloud Librarys (PCL) (Rusu and Cousins, 2011).

3.1. Dual depth cameras calibration and registration

Since a single depth camera has limited scan range, dual-depth cameras from different viewpoints are needed for coverage of a complete pig. Each point clouds from single depth camera have its local coordinate system, and a registration step transforming two point clouds into a uniform coordinate system has to be performed.

The external calibration of dual-depth cameras is implemented by selecting the corresponding points manually. We use the software developed by the institution the authors are affiliated to, N ($N > 3$) corresponding points for each of the two point clouds collected by the two cameras was picked by the user. Then, the software uses the corresponding points to compute the external calibration matrix that consists of rotation and translation. The singular value decomposition method (Arun et al., 1987) is used to calculate the external calibration matrix T.

During data acquisition, both sides of the point clouds of the scene S_1 and S_2 collected from the depth cameras were aligned into a common coordinate system using the external calibration matrix T and registration result S was calculated by the following formula.

$$S = S_1 + TS_2 \tag{1}$$

Fig. 3 shows the two point clouds collected from the dual depth cameras and the registration result of the two input point cloud, and Fig. 2a shows the registration result for the farm scene collected from this system.