A technology of contactless three-dimensional reconstruction of animal models using depth cameras

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Abstract

The paper presents new technology and developed an automated system of expert assessment of animals. The proposed technology is based on contactless three-dimensional reconstruction of animal models using Kinect depth cameras. The paper solves the problem of creating in real-time a three-dimensional model of cattle based on multisensor data from different three cameras. The proposed system of three-dimensional reconstruction of animals allows for high-precision three-dimensional measurements of animals.

Keywords

contactless, three-dimensional reconstruction, depth camera, expert assessment, automated system

1. Introduction

Current trends in the development of industrial technology to produce high-quality meat in the world are associated with the maximum automation of production to minimize production costs while observing generally accepted environmental standards [1-2]. We describe the proposed system for 3-D animal automatic measurement using three RGB-D Kinect cameras. We describe the proposed system that automatically generates the 3-D model of cattle [3]. For the design of the system, we used the Point Cloud Library (PCL).

2. Materials and methods

Data from 50 Hereford cows were collected on July 11th, 2019. The cows were the Hereford breed, kept in a private farm with top dressing with concentrated feed in age from 12 to 15 months, Voronezh region, Russia. We decided to take only 9 main body measurements: withers height, height in the sacrum, chest depth, chest girth, width in maclocks, hip joint width, oblique body length, oblique rear length, chest width, which were manually measured by an expert. Also, live body weight was measured using weight balance. The weights of these animals were between 243 and 605 kilograms (kg). A setup for image recording was built such that it could be placed in the aisle to the hall with automatic feeding systems. All measurements were taken from three points of view on a walking animal.

3-D reconstruction with multiple ICP consists of the following steps: 1) registration of RGB and depth data from the three Kinect cameras; 2) synchronization of the three Kinect cameras; 3) improving the quality of the depth map by depth denoising algorithm based on a novel switching bilateral filter [4]; 4) creation of point clouds using RGB and depth data from the three Kinect cameras; 5) improving the quality of the point cloud by the denoising algorithm ROR; 6) perform adaptive extrinsic calibration of cameras to get the transformation matrices that use point cloud fusion to generate the 3-D model; 7) perform multiple ICP for generating the 3-D model; 8) perform 3-D automatic measurement on the 3-D model.

3. Results and discussion

We validate our system on is point clouds of live cows. Specifically, 50 Hereford cows were captured by using our system for livestock 3-D measures. The segmentation and pose normalization results on these data are good. Error percentage achieved demonstrated that our software can reach levels of measurement accuracy comparable to those obtained by traditional measuring instruments. It should be noted that more accuracy can be obtained by using a more advanced 3-D scanning system. Extracted measurements from the 3-D model of cattle are slightly different from corresponding real-world measurements (Tab. 1). The greatest average difference of 5.8% was obtained in chest girth measurement because chest girth cannot be measured correctly by our system due to under-part missing issue that is caused by the under-part of livestock is usually missed due to occlusion. So, this problem can be solved by adjusting the curve fitting algorithm in the future.

Tables 1

Comparisons between the value of live cow body measurements measured manually and using our system. Withers height (WH), Height in the sacrum (HS), Chest depth (CD), Chest width (CW), Width in maclocks (WM), Hip joint width (HJW), Oblique length of the body (OLB), Oblique rear length (ORL), Chest girth (CG). Min: minimum value of live body measurements. Max: maximum value of live body measurements. Mean: mean value of live body measurements. Average: average percent errors for different traits on the 50 real-world cows. SD: standard deviation for corresponding percent errors

Statistic	WH	HS	CD	CW	WM	HJW	OLB	ORL	CG
Min (cm)	100	100	50	29	35	35	124	35	145
Max (cm)	132	137	70	61	51	56	459	58	207
Mean (cm)	119	123	63	43	43	47	156	44	182
Average (%)	4.7	4.5	2.9	3.6	2.7	2.3	3.1	4.1	5.8
SD (%)	4.9	2.1	2.4	4.8	4.1	4.2	2.7	3.4	5.2

4. Conclusion

The automated 3-D point clouds analysis system for the body measurement of cows was successfully developed and tested. We have shown results on real-world datasets that demonstrate that our system can reach levels of measurement accuracy comparable to those obtained by traditional measuring instruments. The experiments have shown that the proposed system for 3-D livestock measuring can provide accuracy. In the future, only one-half of the captured animal can be measured by determining the symmetry and approximation of the second half of the animal. Another big issue of livestock body measurement based on point clouds is how to get the specific markers of livestock automatically, which will be the next priority for researchers.

5. References

[1] Ruchay, A. A depth camera-based system for automatic measurement of live cattle body parameters / A. Ruchay, K. Dorofeev, V. Kalschikov, V. Kolpakov, K. Dzhulamanov // IOP Conference Series: Earth and Environmental Science. – 2019. – Vol. 341. – P. 012148.

[2] Ruchay, A.N. Accurate 3d shape recovery of live cattle with three depth cameras / A.N. Ruchay, K.A. Dorofeev, V. Kalschikov // IOP Conference Series: Earth and Environmental Science. – 2019. – Vol. 341. – P. 012147.

[3] Ruchay, A. Accurate body measurement of live cattle using three depth cameras and non-rigid 3-D shape recovery / A. Ruchay, V. Kober, K. Dorofeev, V. Kolpakov, S. Miroshnikov // Computers and Electronics in Agriculture. – 2020. – Vol. 179(12). – P. 105821.

[4] Ruchay, A.N. A novel switching bilateral filtering algorithm for depth map / A.N. Ruchay, K.A. Dorofeev, V. Kalschikov // Computer Optics. – 2019. – Vol. 43(6). – P. 1001-1007. DOI: 10.18287/2412-6179-2019-43-6-1001-1007.