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Research Note

A multi-Kinect cow scanning system: Calculating linear traits from manually marked recordings of Holstein-Friesian dairy cows

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Microsoft Kinect systems have already been used for detecting lameness and determining body condition in dairy cattle. A combination of six Kinect cameras was used with the goal of measuring linear descriptive traits. To access the precision of measurements gathered with a fixed installed recording unit, front teats and ischial tuberosities were marked manually in the recordings. Teat lengths and heights of ischial tuberosities were then calculated from the 3D coordinates. Recorded with cattle standing still and walking, teat lengths showed a standard error range from 0.7 mm to 1.5 mm and 1.8 mm–3.2 mm, respectively. The standard errors regarding the heights of the ischial tuberosities ranged between 2.4 mm and 4.0 mm in standstill and between 14.0 mm and 22.5 mm when measured on a walking cow.

1. Introduction

An increasing number of dairy science related studies successfully have used low cost off-the-shelf 3D cameras such as the Microsoft Kinect (Spoliansky, Edan, Parmet, & Halachmi, 2016; Viazzi et al., 2014), or ASUS Xtion Pro (Kuzuhara et al., 2015) for lameness detection or determining body condition. Salau, Haas, Junge, Leisen, and Thaller (2015) presented the concept of a 3D cow scanner. Combining the fields of view of six Microsoft Kinect cameras, 3D information of a high percentage of the surface of cows can be recorded in free walking and information retrieved. The goal for the development of the 3D cow scanners is the evaluation of the animal body metrics. Dairy cattle breeding decisions are based on the manual and visual evaluation of cow exterior by highly trained classifiers. This linear description is meant to score traits individually and measure degree rather than desirability ("International Committee for Animal Recording: Conformation recording dairy and beef cattle", 2015). A general consensus has been reached concerning the linear descriptive traits. The primary traits were scored on 9 or 50 point scales (Deutscher Holstein Verband e.V., 2016; "Holstein Association USA, Inc.: Linear Descriptive Traits", 2014), but they could also be given as lengths and angles along the cow surface. Whilst measuring these traits using methods of computer vision, it seemed worthwhile to remove the influence of human classification. No holistic attempt has been made so far to automate conformation recording apart from

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analyses of singled-out body parts (i.e. Zwertvaegher, Baert, Vangeyte, Genbrugge, & Weyenberg, 2011).

In this study, a fixed installation of a 3D cow scanner was tested by recording test cows in free walking and standstill, from both sides. As 3D object recognition is a difficult and widely studied topic (Gordon & Lowe, 2006; Shotton et al., 2013; Toshev, Makadia, & Daniilidis, 2009), the automation of body part determination for measuring linear traits could become a major challenge in further development. To better understand the data before addressing this task, a selection of body characteristics was measured after manually determining the respective body parts in the test data, which should give insights into the precision of the measurements as well as the feasibility of the approach in general. Teats and ischial tuberosities were marked manually in depth data of standing and freely walking cows. Small (teat lengths) and larger (height of ischial tuberosities) distances in the recorded point cloud data were then calculated and compared, giving information on precision and the differences between standing and walking animals.

2. Material and methods

2.1. *Microsoft Kinect cameras*

Microsoft Kinect cameras (V1) combine an RGB-camera with a depth sensor ("PrimeSense Supplies 3-D-Sensing Technology to 'Project Natal' for Xbox 360", 2010; "Kinect for Windows", 2014), which acquires depth data using the principle "Structured Light" (Andersen et al., 2012). The Kinect camera provides 57° horizontal and 43° vertical field of view (FOV) and can record with a framerate of 30 images s^{-1}. Depth measurement resolution decreases with distance. At 0.5 m and 5 m approximately 1 mm and 75 mm resolution was observed, respectively. Depth data was stored in 640 × 480 matrices (depth maps), holding the distances between scenery points and camera. Recording with multiple Kinect cameras, their synchronisation, data storage, and extrinsic calibration were handled during the preliminary development steps (Salau, Haas, Junge, & Thaller, 2016b; Salau, Haas et al., 2015).

2.2. *Recording unit*

A wooden frame (passage height and width ~2 m) was equipped with six Kinect cameras. On each side of the frame a Kinect camera was located at 0.6 m height with a horizontal line of sight (designated as side view camera). Additionally, a pair of Kinect cameras was positioned on the diagonal sections of the frame at ~1.95 m height (designated as top view cameras). Their lines of sight hit the ground at ~45° (Fig. 1A). The recording unit was installed in a separate room at the Karkendamm research farm of Kiel University, Northern Germany (Fig. 1B). A permanently installed round path was provided so that the cows could be recorded freely walking without being led in a halter. As the horizontal FOV of one Kinect camera was too small to record full gait cycles of the animals, the horizontal fields of view of the paired top view cameras were combined by mounting them at an angle of 56° between their front faces (Fig. 2A). The smallest distance to ensure that the Kinect cameras from the same pair were not seen by each other was 27.25 mm (Fig. 2B). Their horizontal FOVs overlapped only by 2° to minimise interference between cameras and to maximise the combined horizontal FOV (112°, Fig. 2C).

2.3. *Data collection and recorded cows*

Recording took place on 13th November, 2015 at the Karkendamm research farm of Kiel University. Four Holstein-Friesian cows were randomly chosen from the herd. Each cow had eight passes through the frame and was additionally recorded in standing still for ~3 min. The test cows were positioned with full weight placed on the right rear leg and with the udder visible in the left side view camera's FOV. Information on the recorded test cows is shown in Table 1. Streams of depth data showing walking cows were obtained from all cameras simultaneously. Due to processing and filesystem operations the recording framerate was approximately 20 images s^{-1}.

2.4. *Obtaining traits*

RGB data was not recorded in this setting. Depth maps of the left side view and one of the top view cameras on the right (left/

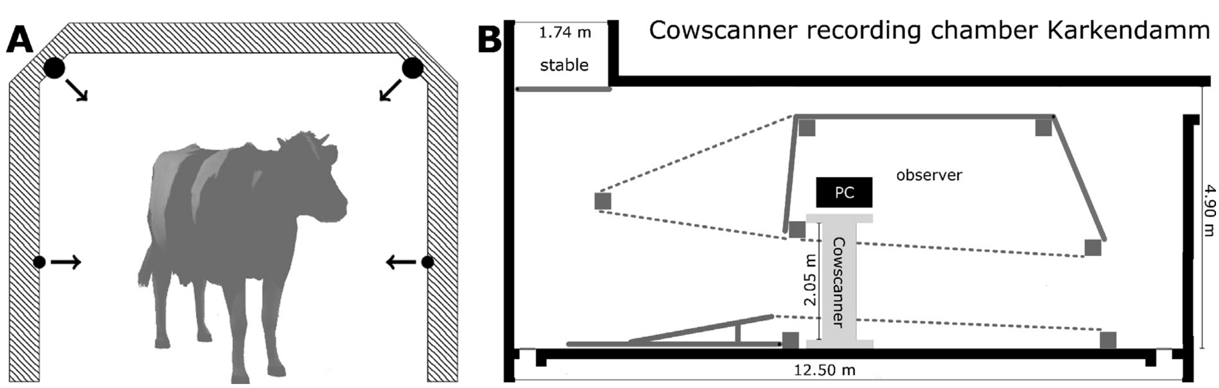

Fig. 1 – A: Schematic representation of the recording unit. A frame was equipped with six Kinect cameras. On each side one camera was mounted in 0.6 m height and two in ~2 m height (details given in Fig. 2). The black arrows indicate their views. B: Schematic representation of the installation of the recording unit. The cows could access the recording chamber directly from the stable. Spring gates (dashed grey lines) and pipes (solid grey lines) formed a round path that guided them through the framework.