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Motion Tracking of Animals for Behavior Analysis

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Abstract. In this paper, we are presenting our results for motion tracking animals in stabling. This system was used in order to record the behavior of pigs in stabling. We used an object-oriented method for our application instead of a block-oriented method. First of all, we calculated a reference image. This image was used in order to separate the objects from the background. Then, object pixels were grouped into an object by the line-coincidence method. Movement parameters are calculated for each object. Finally, an object correction is done for those objects that were occluded by the boundary of the stabling. The resulting tracking path and the movement parameters are displayed on screen for the user.

1 Introduction

Researchers and farmers record the movements of animals on video in order to observe animal behavior. Afterwards, they analyze these videos by looking up each image sequence and taking notes about the spatial position of each animal. This is a very time consuming process. However, such an observation of animals is important in order to understand the behavior of animals in stabling and other environments [1][2]. The resulting knowledge can help to improve animal welfare as well as meat quality.

The task of behavior analysis is not only important for the study of animal welfare, it also becomes important for many other tasks such as group behavior analysis in public traffic areas, soccer game reporting and pharmacological studies.

An automatic system has to recognize the object and to track the object before it is possible to describe the semantic concepts of the behavior of the observed object such as object "stand", "moves" or more complex concepts such as object under "nervous excitement". In this paper, we are presenting our results for motion tracking of pigs in stabling.

Visual object tracking has become an important subject in computer vision. We can identify block-oriented and object-oriented methods [3]. An object-oriented method is described in Mae et. al [4]. They combined the optical flow with edge detection in order to separate objects from background. The intention of this work is contour detection of moving objects in a highly structured background. In Hoetner et. al [5] a block-oriented approach is described that uses the signal difference and the texture for the detection of moving objects. In Iketani et. al [6] the segmentation of the images is done by partitioning image into blocks and determining the value of the optical flow for each block. Regions with the same value for the optical flow were grouped into one object. That allows us to detect objects on an in-stationary background. For our application, we chose an object-oriented method to prevent objects getting separated or combined together by the blocks.

2 Image Acquisition

The movements of the pigs in stabling were recorded by a video camera when the pigs came into stabling for the first time. The length of the video was from 20s to one minute. The camera had a fixed position that allowed us to look at the stabling diagonally from the top. In each video, we could see the boundary of the stabling. First, images from the empty stabling were taken for 0.5 s. The spatial resolution of the image sequence is 768 x 576 pixels for each image. It is possible to see the time in each video at the lower right corner.

3 Outline of our Method

The outline of our method is shown in Figure 1. The image sequence of the empty stabling is extracted from the video and given to the pre-processing unit. This unit calculated a reference image, a threshold and new matrix which contains the boundary of the stabling. Afterwards, objects and background were separated in each image of the video sequence based on the reference image. Then, objects were determined in the image and the motion parameters were calculated. Objects may be occluded by the boundary of the stabling. The objects and motion parameters were corrected for this reason. Finally, the tracking path and the motion parameters were displayed on screen.

4 Image Pre-Processing

The image sequence from the empty stabling $\{anf_k(i,j) : k = 1,...,k\}$ (see Figure 2) was extracted from the video sequence and a reference background image was calculated from these images:

$$ref(i,j) = \frac{1}{k}\sum_{k=1}^{K} anf_k(i,j) \quad \textbf{(1)}$$

In addition to that, we extracted the boundary of the stabling from the reference image *ref(i,j)* and stored it in an image matrix called *gitter(i,j)*. For that reason, we calculated the histogram of *ref(i,j)* and determined the grey level threshold which allowed us to separate the background from the boundary of the stabling. A pixel in the matrix *gitter(i,j)* is one if the pixel belongs to the boundary of the stabling and it is zero if the pixel does not belong to the boundary.

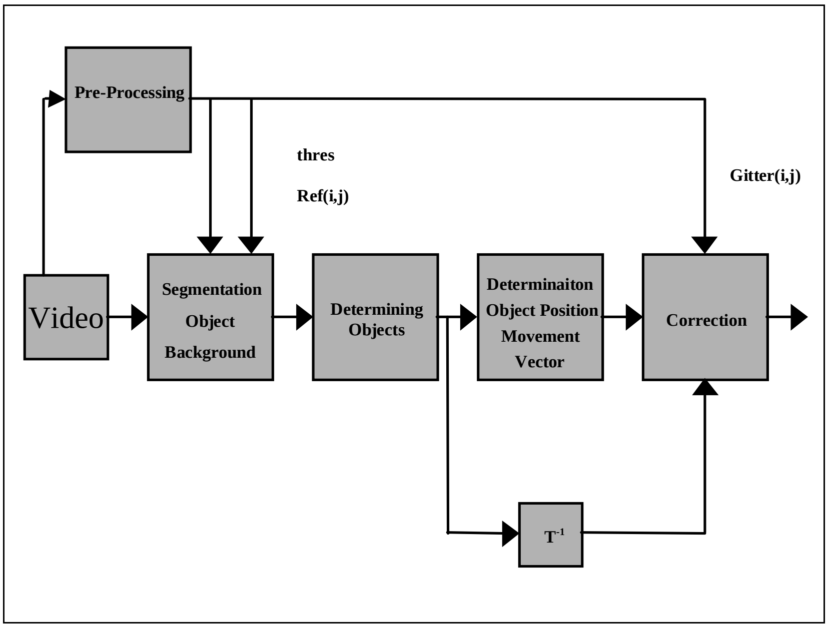

Fig. 1. Overall Structure of our Algorithm

5 Separation of Object and Background

A threshold was determined from the initial images and the reference images in order to separate objects and the background. We determined the variance from the difference of the initial images and the reference image:

$$sq = \frac{1}{k-1}\sum\left(anf_k(i,j) - ref(i,j)\right) \quad (2)$$

Afterwards, we calculated the histogram over all difference pixel. The threshold for the object segmentation was determined:

$$\sum_{s=0}^{grenz} h(sq) = 0.95 \qquad thresh = 2 \bullet grenz \tag{3}$$

Now, the reference image *ref(i,j)* was subtracted from the actual image *act(i,j)*. The resulting image was segmented into object pixel and background pixel based on the threshold described above. The resulting binary image has the name *arb(i,j*). The object pixels were grouped into separate objects by the line coincidence method [7]. Each object was labelled by an object number *objnr*. Objects smaller than a predefined threshold were interpreted as image noise and eliminated from the list of objects.
After the first real object was found the determination of the object position and the movement vector were started.

6 Determination of the Object Position and the Movement Vector

The center of gravity *mi* and *mj* were determined for each object. Then, the movement vector of each object was determined by the following equation:

$$\begin{aligned} bewi(objnr,k) &= mi(objnr,k+n+1) - mi(objnr,k) \\ bewj(objnr,k) &= mj(objnr,k+n+1) - mj(objnr,k) \end{aligned} \tag{4}$$

Unfortunately, this method for the determination of the movement vector has some disadvantages. The method can not determine rotations of the object according to its inner axis and 3D movements. However, it was sufficient for our problem.
Another parameter that is determined is the area of each object *anz* at each time *t*. That means that for each object we determined *objnr, mi, mj, bwei, bewj and anz*. These parameters are the basis for further determination.

7 Correction of the Objects and the Object Parameters

The boundary of the stabling can sometimes partially occlude the pigs. For instance, objects may be separated by the boundary. The computed movement parameters were used to correct these disturbances and deformations. The binary matrix *arb(i,j,k)* at the time *k* were taken in order to prove, for each object, if the object was behind or in front of the boundary. In the case where the object was in front of the boundary then the object occluded the boundary and no correction was necessary. Only in the case, where the object was behind the boundary was a correction necessary. For that the object was extracted from *arb(i,j)* so that we obtained a new matrix *arb1(i,j)* that only contained the pixel of this object. The matrix *arb1(i,j)* was added up with the matrix *gitter(i,j)*. In the case that the resulting matrix had the value “2” inside then no correction was necessary. If this case did not occur then a dilation was done on *arb1(i,j)*

$$arb1(i,j) \oplus M = \{(i,j) : M_{i,j} \cap arb1(,) \neq 0\} \quad \textbf{(5)}$$

M is a 3 x 3 mask containing the value "1" and $M_{i,j}$ is the mask M that was shifted to the pixel *(i,j)*. The resulting matrix was computed with the mask *gitter (i,j)* by the *logical AND* function. If the result was zero, then the object was not occluded by the boundary of the stabling and correction was not necessary. A correction was made if the resulting values of this operation were "1". The object was isolated from the matrix *arb(i,j,k-1)*. Then, it was shifted by the calculated motion vector *(=(trans,i,j))* and combined with the matrix *arb1(i,j)* by the logical AND function. For the resulting corrected object the proof was carried out as to whether has a nonempty intersection with the object in *arb(i,j,k)*. Then, these objects were combined to a single object. Afterwards, the *parameter mi(,), mj(,), bewi(,), bewj(,),* and *anz* were calculated for the corrected object.

8 Output of the System

The resulting tracking path of each object is displayed on screen. Figures 3-8 show images at different times t and the tracked path of the objects. It shows that we are able to track the objects by our algorithm.
However, on the recorded path we can see that the movement of the pig is not a smooth line. The pigs are tripping a bit back and forth at the same place. They rotate on their own axis.
Our system records for each pig the coordinates, motion parameters and the time. It gives us the basic information needed for behavior analysis. The next step must be the mapping of the information extracted from the image to the semantic concepts that the veterinarian needs for his analysis. Only when this task is solved do we have a fully automatic system. However, it also shows the complexity of the task of behavior analysis. The tracking of the objects is not simple and it is even harder in a real world environment. The next step, the mapping of the image information to the semantic concepts needs a clear understanding of what the concepts are and how we can describe them by the image content.
Recently, the veterinarians have shown they are happy with a listing of the coordinates, the motion parameters and the associated time for each pig.

9 Conclusion

We have presented our system for motion tracking of animals in stabling. Our system was used for the analysis of movements of pigs when they enter new stabling.
Furthermore, we have investigated other methods for motion tracking. However, we found that our method has several advantages over these methods for our application. First of all, it is easy to calculate. Secondly, it can correct occluded object parts, which

helps to improve the determination of the object position and the motion parameters. Finally, it takes into account the changing shape of the objects that, for example, occurs by rotation of an object.

Acknowledgement

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Fig. 2. Empty stabling

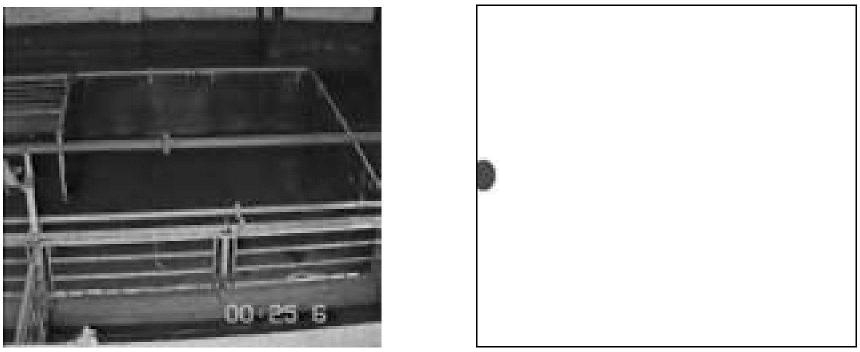

Fig. 3. Original image (first pig comes into the stabling) and result of motion analysis

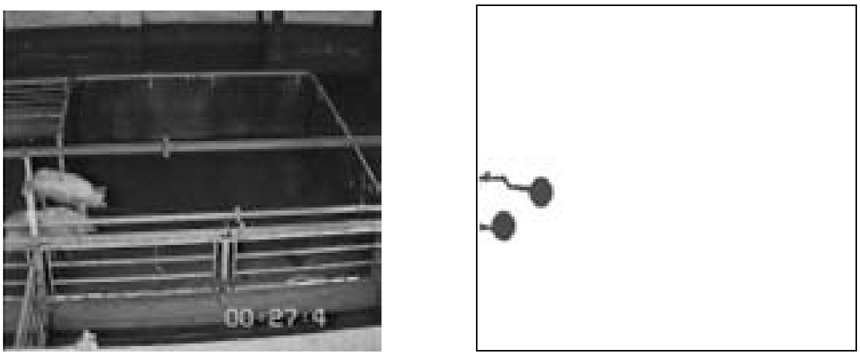

Fig. 4. Image number 82 and tracking path of pigs

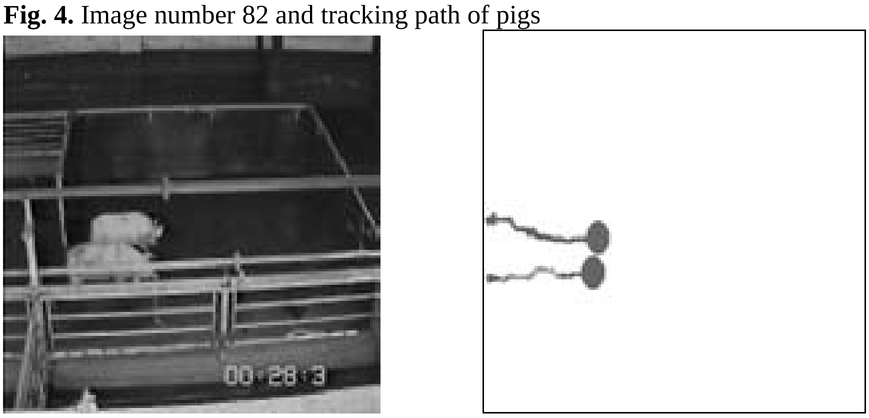

Fig. 5. Image number 105 and tracking path of pigs

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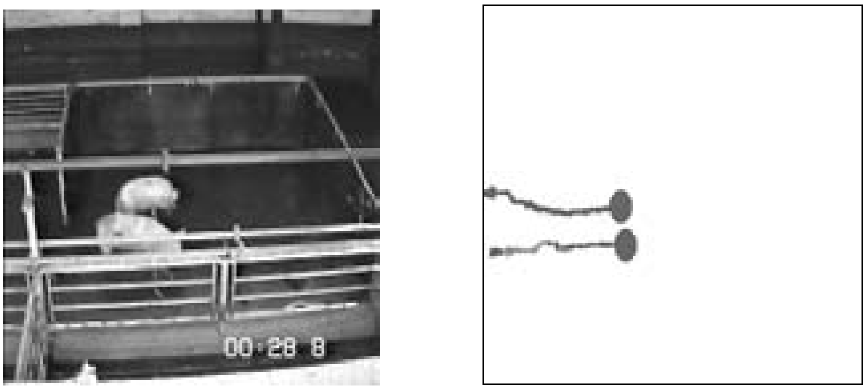

Fig. 6. Image number 118 and tracking path of pigs

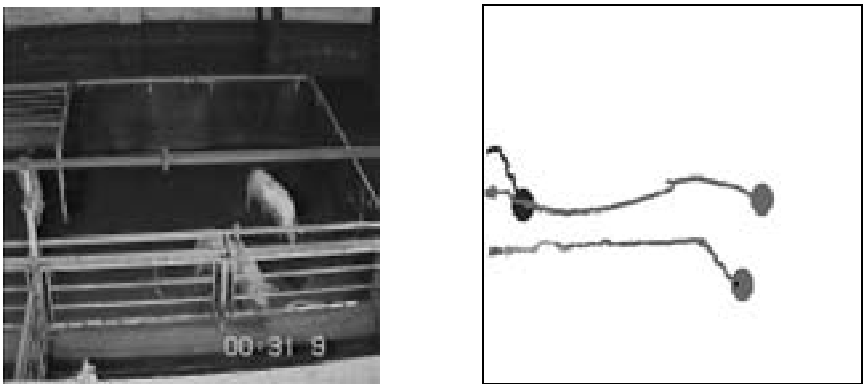

Fig. 7. Image number 205 and tracking path of pigs

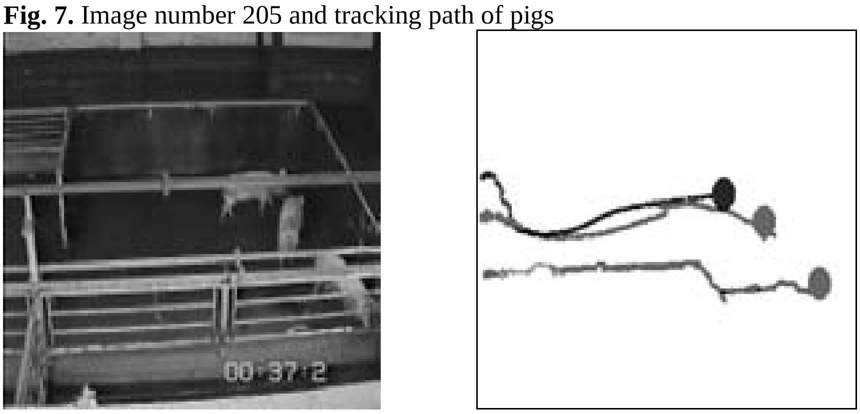

Fig. 8. Image number 327 and tracking path of pigs

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