Protocol 12
Related Work of Gait Analysis and Data Preprocessing

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There are some neural networks proposed for spatial-temporal feature extraction, mainly used for video analysis, such as action or gait recognition. Even though these networks were used for human action analysis, they can be applied to pose and gait analysis of cows through transfer learning. Three networks are summarized in the following.

Data Preprocessing

1. Cow Extraction

Last week, the TensorFlow object detection API was fine-tuned for cow detection. The summary of the process is as follows:

- Prepare images
- Data annotation: Use LabelImg (https://github.com/tzutalin/labelImg) to annotate the data by drawing bounding boxes around the object of interest. The annotation files (.xml) will be generated accordingly.
- Create TFRecord file from data: Convert annotation files to .csv file, and then to .record file.
- Create model config file, which can be chosen from: the source below
  https://github.com/tensorflow/models/tree/master/research/object_detection/samples/configs

  The number of class and some of the paths need to be changed.
- Training: run the "train.py" in TensorFlow object detection API

2. Pose Estimation

DeepLabCut (https://github.com/AlexEMG/DeepLabCut) is used to annotate the keypoints for pose estimation. The training procedure is summarized in protocol5. There are 18 keypoints in total:

- forehead
- atlas joint
- neck
- withers
- back (middle point between withers and hook)
- hook (the point extended vertically from the hook to the back)
- two carpal joints (front legs)
- two hock joints (rear legs)
- four fetlock joints
- four hooves

The training data include 240 frames (12 videos $\times$ 20 frames per video). Results after 30000 iterations: train error: 3.42 pixels, test error: 7.14 pixels. As the test error is larger than training error, some generalization strategies should be applied, such as model retraining with more data.

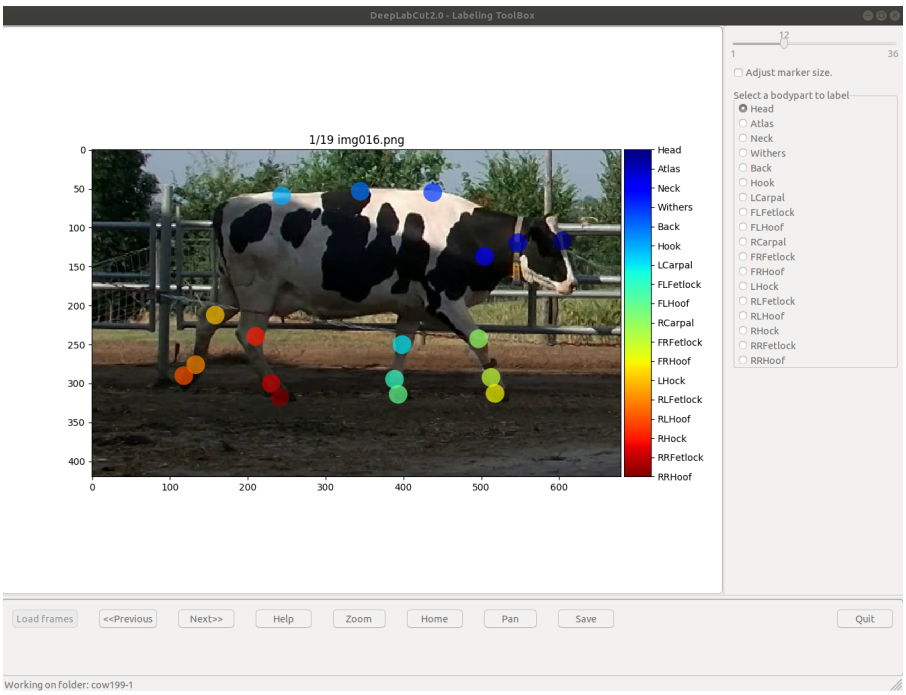

Figure 1: DeepLabCut annotation GUI.

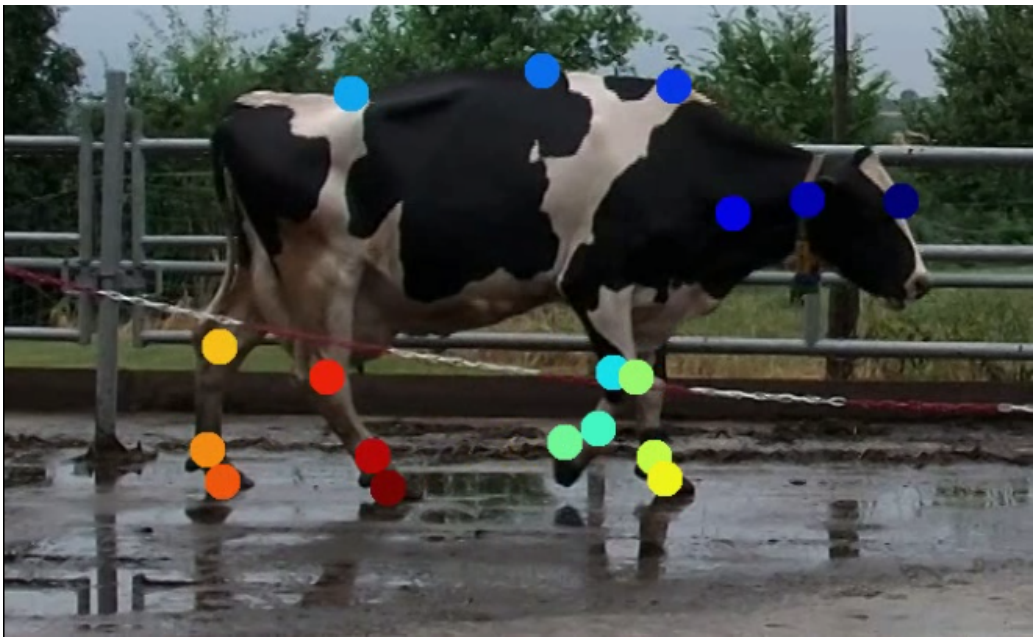

Figure 2: Test result of keypoints tracking using DeepLabCut.

Related Work of Gait Analysis

1. Detection of Abnormal Gait from Skeleton Data [1]

- **Reference:**

  Meng, Meng, et al. "Detection of abnormal gait from skeleton data." VISIGRAPP. 2016.

- **Input data:** Depth images from RGB-D camera

- **Method:**

  Skeleton is extracted using the approach based on random forest [2]. The inter-joint distances are computed for each frame, and a feature vector is formed by concatenating the distance vector of n consecutive frames. Random forest is applied to classify the gait (normal or four abnormal gait patterns).

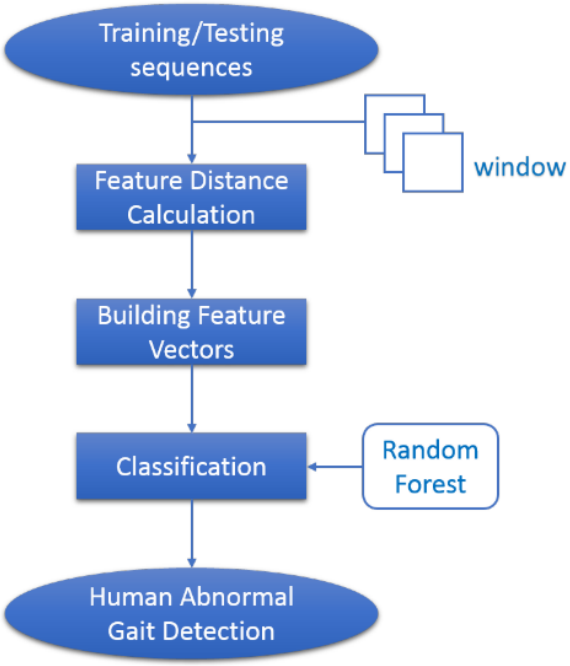

Figure 3: Abnormal gait detection flowchart.

- **Notes & comments:**
  - The classification is more accurate when more frames (temporal information) are included.
  - Some distances are more relevant for abnormal gait detection: distance between knee and foot, distance between feet, distance between ankles.
  - The distances between joints over a sequence of frames are good features for gait analysis.
  - The paper considered the distances between all the joints, which may be redundant since some distances may remain constant

2. Abnormal Gait Detection Using Joint Motion History [3]

- **Reference:**

  Chaaraoui, Alexandros Andre, Jos Ramn Padilla-Lpez, and Francisco Flrez-Revuelta. "Abnormal gait detection with RGB-D devices using joint motion history features." 2015 11th IEEE international conference and workshops on automatic face and gesture recognition (FG). Vol. 7. IEEE, 2015.

- **Input data:** Skeleton sequence from RGB-D images

- **Method:** The 3D skeletal data are tracked over a number of frames and combined into a 3D volume. The volume is then projected onto its three orthogonal axes by applying dimensionality reduction. Spatio-temporal feature are learned by a classification algorithm called BagOfKeyPoses.

- **Notes & comments:**
  - The authors proposed the joint motion history (JMH) as a spatio-temporal feature for gait analysis.
  - The proposed feature requires 3D skeletal data, so the method needs to be modified to process 2D data.

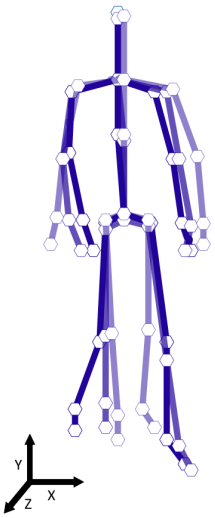

Figure 4: Superposition of normalized skeletons from three frames.

References

[1] M. Meng, H. Drira, M. Daoudi, and J. Boonaert, "Detection of abnormal gait from skeleton data," in *VISIGRAPP*, 2016.

[2] J. Shotton, A. Fitzgibbon, M. Cook, T. Sharp, M. Finocchio, R. Moore, A. Kipman, and A. Blake, "Real-time human pose recognition in parts from single depth images," 2011.

[3] A. A. Chaaraoui, J. R. Padilla-López, and F. Flórez-Revuelta, "Abnormal gait detection with rgb-d devices using joint motion history features," in *2015 11th IEEE international conference and workshops on automatic face and gesture recognition (FG)*, vol. 7, pp. 1–6, IEEE, 2015.