Protocol 16: Result Analysis 2

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Spatial Temporal Graph Convolutional Networks (ST-GCN)

As mentioned in the protocol15, the data quality seemed to one of the main reason of poor prediction of locomotion score. After additional training of pose estimation (100 annotated frames with pre-trained network), the result does not seem to improve much. Three different sets of keypoints were used to train the spatial temporal graph convolutional networks, as described below.

1. Data

- **Classification:** The initial step treats the task as a classification problem. Even though the locomotion scores have five levels from 1 to 5, four classes are considered here:
  - Class1: LS 1-2
  - Class2: LS 2-3
  - Class3: LS 3-4
  - Class4: LS 4-5 (containing 5)
- **Dataset:** Each data sample contains the coordinates of 18 skeleton joints from 300 video frames and a locomotion score as the label. The dataset has 501 samples, divided into training and test sets with a 70/30 ratio.
- **Keypoints:** Figure 1 shows the 18 keypoints (skeleton joints) from by pose estimation. Since the hook joint (keypoint 5) is comparatively stable, the coordinate of all the points are calculated from the point instead of the absolute position in the frame.

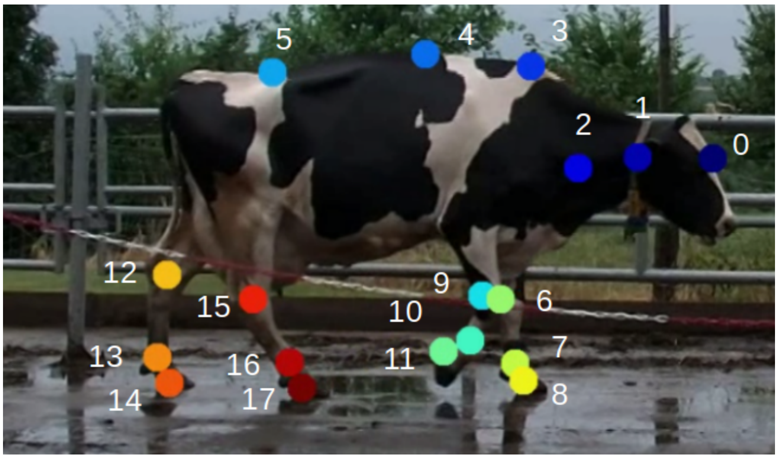

Figure 1: The 18 keypoints extracted from videos for lameness detection.

2. Result and Discussion

The model was trained with a batch size of 10 and an initial learning rate of 0.1 for 80 epochs.

- **All keypoints:**

  All the keypoints are considered in this case, and the point at the neck (keypoint 2 in Figure 1) is considered as the center of the graph. Both the precision and recall values are higher for the boundary classes (class 1 and 4). The model has difficulty differentiating between class 1 and 2.

Table 1: Confusion matrix: all keypoints

	Predicted Class 1	Predicted Class 2	Predicted Class 3	Predicted Class 4
Actual Class 1	43	16	3	2
Actual Class 2	18	12	8	3
Actual Class 3	7	6	11	5
Actual Class 4	3	1	3	10

Table 2: Precision and recall: all keypoints

Class	Precision	Recall
1	0.606	0.672
2	0.343	0.293
3	0.440	0.379
4	0.500	0.588

- **Upper-body keypoints: points 0-5**

  Only six keypoints are considered. The first three points contain the information of head bob, and the last three points describe the level of back archness. It turns out that the recall of class 1 is much higher than the other classes, which may indicate that the upper-body joints have relatively large amount of information of healthy cows.

Table 3: Confusion matrix: upper-body keypoints

	Predicted Class 1	Predicted Class 2	Predicted Class 3	Predicted Class 4
Actual Class 1	47	16	0	1
Actual Class 2	23	12	4	2
Actual Class 3	12	5	10	2
Actual Class 4	4	2	5	6

Table 4: Precision and recall: upper-body keypoints

Class	Precision	Recall
1	0.547	0.734
2	0.343	0.293
3	0.526	0.345
4	0.545	0.353

- **Gait keypoints: points 6-17**

  Points 6 to 17 are the joints of the legs. Similar to the previous cases, the precision and recall are higher for boundary classes. However, the overall prediction is slightly better using just the gait features. As shown in Table 7, the accuracy of lameness detection is 0.550 using the gait keypoints.

Table 5: Confusion matrix: gait keypoints

	Predicted Class 1	Predicted Class 2	Predicted Class 3	Predicted Class 4
Actual Class 1	42	18	2	2
Actual Class 2	11	22	5	3
Actual Class 3	7	9	11	2
Actual Class 4	3	1	5	8

Table 6: Precision and recall: gait keypoints

Class	Precision	Recall
1	0.667	0.656
2	0.440	0.537
3	0.478	0.379
4	0.533	0.471

Table 7: Accuracy of lameness detection of different sets of keypoints.

	All Joints	Upper-Body Joints	Gait Joints
Accuracy	0.503	0.497	0.550

3. Next Step

Since there is still much space to improve, different strategies should be considered. There should be a closer look at the data that lead to incorrect prediction in order to find out more possible reasons of poor performance. Pose estimation still needs to be improved, especially the most vital points such as the back and the hooves. Besides, some keypoints may be added near the center of the cow, such that the joints of upper and lower body can be linked together. The model structure and the hyper parameters may play important roles as well.