Tracking animal identities with machine learning to analyze cichlid aggression

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Objective

Aggression is a central characteristic of social animal behavior that can drive early life development. We can use the social cichlid fish *Astatotilapia burtoni* as a model to study aggression by analyzing stereotyped chase behaviors defined by simple metrics such as changes in velocity. This enables a computer based data collection process, streamlined through the use of the SLEAP machine learning program. This method seeks to translate large quantities of cichlid video into positional coordinate data of multiple points on the animal's skeletal limbs. Optimizing identity tracking ensures that aggressive behaviors can be attributed to individual fish. Machine learning enables the identification of the visual elements through an algorithm that learns visual element identifiers through manually labeled examples. We predict that machine learning algorithms incorporating flow tracking, instance similarity, and Hungarian matching will produce the lowest relative error rate.

Method of Identity Error Measurements

SLEAP applies three primary parameters to match identities across frames

Skeleton bounding box

Similarity methods

- Centroid - Distance between instance centroid
- Instance - Similarity between each skeleton node
- IOU - Overlap between surrounding skeleton box

Matching method - By maximum likelihood estimation (MLE) comparison

- Greedy - Optimize highest ID match score first
- Hungarian - Optimize average ID match values

Tracker method

- Simple - Base matching off of the previous frame(s)
- Flow - Predict fish location based on movement

To compare the error rate between models, only frames in which ID swap errors may occur are considered, represented as:

Relative ID error rate = number of frames with error / total frame count in which one model produces error

Identity error occurrences are visualized in Figure 3, involving a skeleton prediction jumping from one fish to another.

Tracked Videos

#	Camera	Training Set	Length
1	Basler	Included	5 min
2	Raspberry Pi	Not included	30 min
3	Raspberry Pi	Included	30 min

Figure 1. The Basler camera video is used as a control due to known high performance in identity matching. Tracking for video 2, not implemented in the data set, and video 3, which was in the training data, are displayed in the figures.

Application of SLEAP Inbuilt Parameters in Experimental Trials

Tracking Parameter Settings

Trial #	Model used	Tracker method	Similarity method	Matching method	Target cull	Kalman filter	Kalman filter nodes
Desc.	# of frames	none, simple, flow	instance, centroid, iou	greedy, Hungarian	Y or N	Y or N	List of #'s 1 through 8
1	1046	simple	centroid	greedy	Y	N	N/A
2	1046	simple	instance	greedy	Y	N	N/A
3	1046	simple	iou	greedy	Y	N	N/A
4	1046	flow	centroid	Hungarian	Y	N	N/A
5	1046	simple	centroid	Hungarian	Y	N	N/A
6	1046	flow	instance	Hungarian	Y	N	N/A
7	1046	flow	iou	Hungarian	Y	Y	(1, 2, 3, 4)
8	1046	simple	iou	Hungarian	Y	Y	(1, 2, 3, 4)
9	1473	simple	iou	Hungarian	Y	Y	(1, 2, 3, 4)

Figure 2. Parameter settings between trials. Eight arrangements of tracking, similarity, and matching methods were implemented in error analysis. Additionally, use of Kalman filters and models with larger training data sets were compared. The number of each trial is referenced in Figure 3. The list of nodes for Kalman filters refers to the portion of the fish skeleton model used. Nodes 1-4 reference all relevant head features of the fish ID.

Identity Error Occurrences

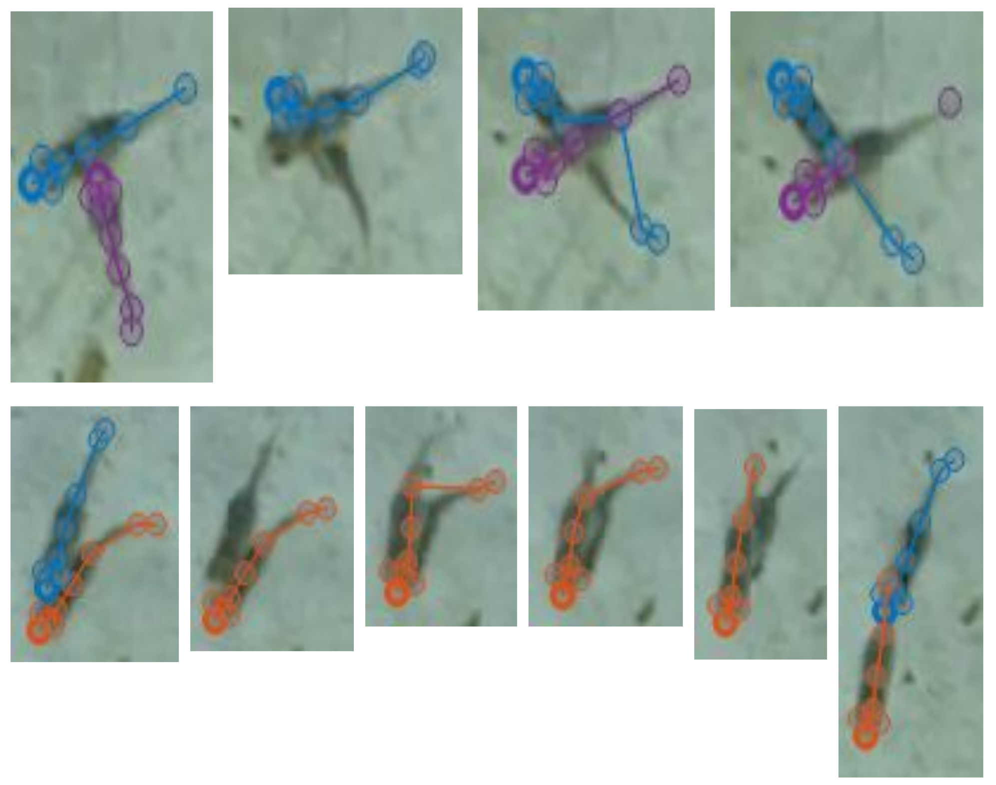

Figure 3. Progression images are shown for two examples of occurrences of identity swaps, in which the tracking skeleton associated with one fish jumps or swaps to another fish.

Minimizing Error Rate in Individual SLEAP Parameters

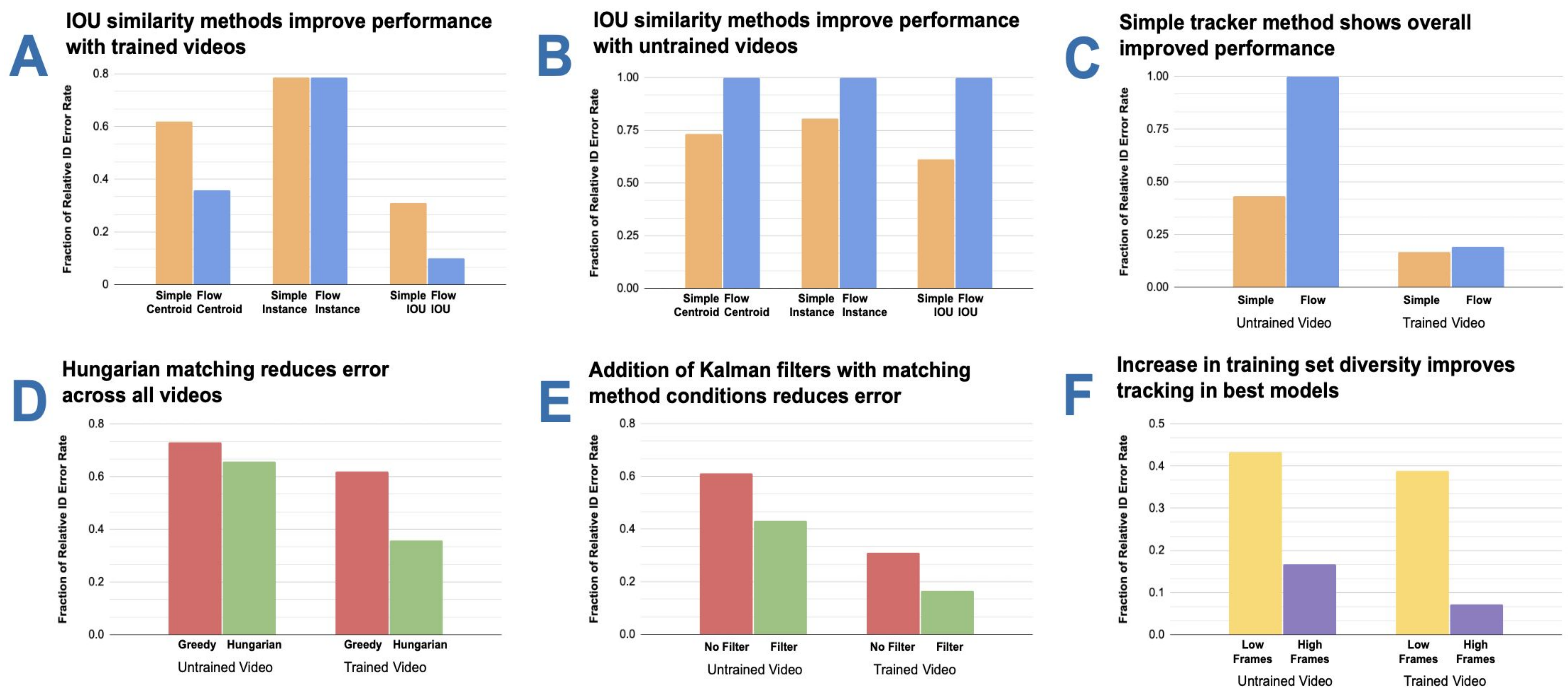

Figure 4. A, B. Three similarity methods are compared between two parameter cases, showing a uniform reduction of error in trained and untrained videos. Compares parameter sets 1, 2, 3, 4, 6, and 7. **C.** Tracker methods as an isolated parameter show a reduction of performance utilizing flow matching. Compares parameter sets 8 and 7. **D.** Matching methods as an isolated parameter show a consistent reduction of error in both high and low performing videos. Compares parameter sets 1 and 5. **E.** Kalman filter were added in parallel to matching method parameter changes for a reduction of error. Compares parameter sets 3 and 8 **F.** Increasing training data set diversity and size show a reduction of error rate in both high and low performing videos. Compares parameter sets 8 and 9. The best performing parameters were simple tracking, IOU similarity, and Hungarian matching, utilizing Kalman filters.