# Automatic identification of individual African leopards in unlabeled camera trap images


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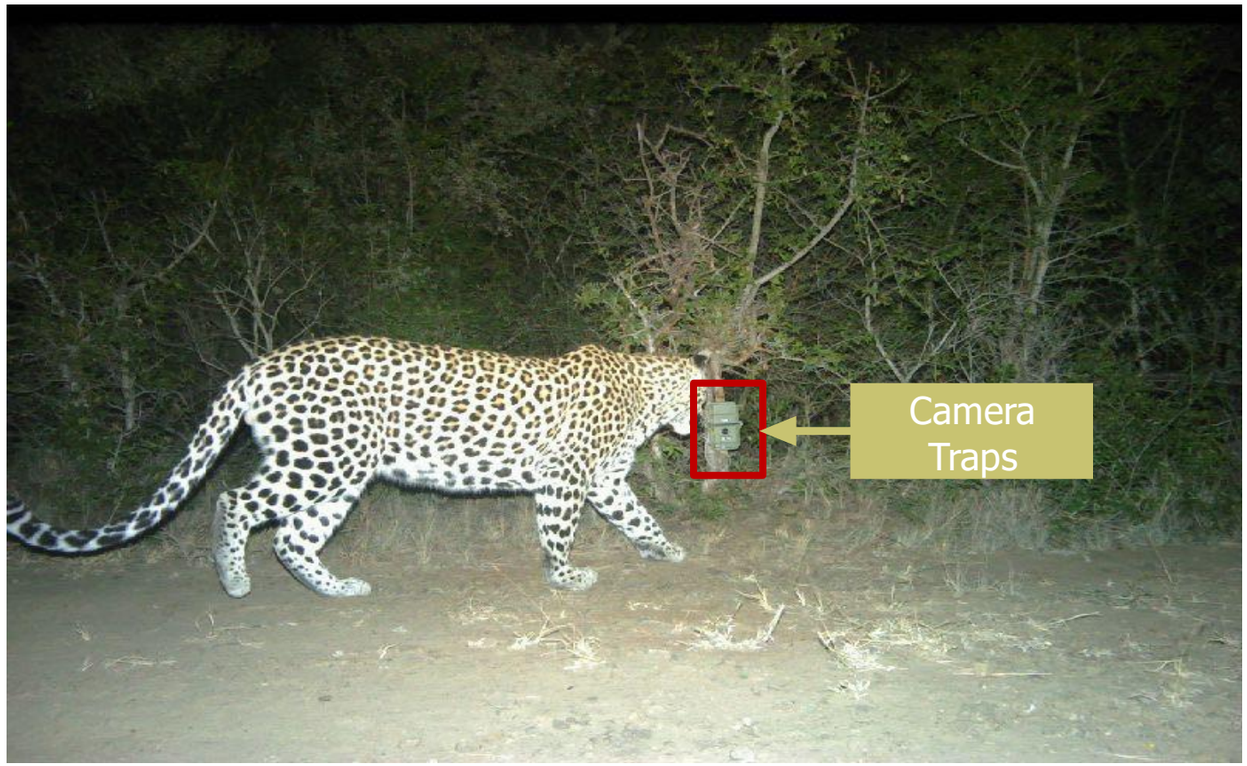
PANTHERA

ATLANTA 2025

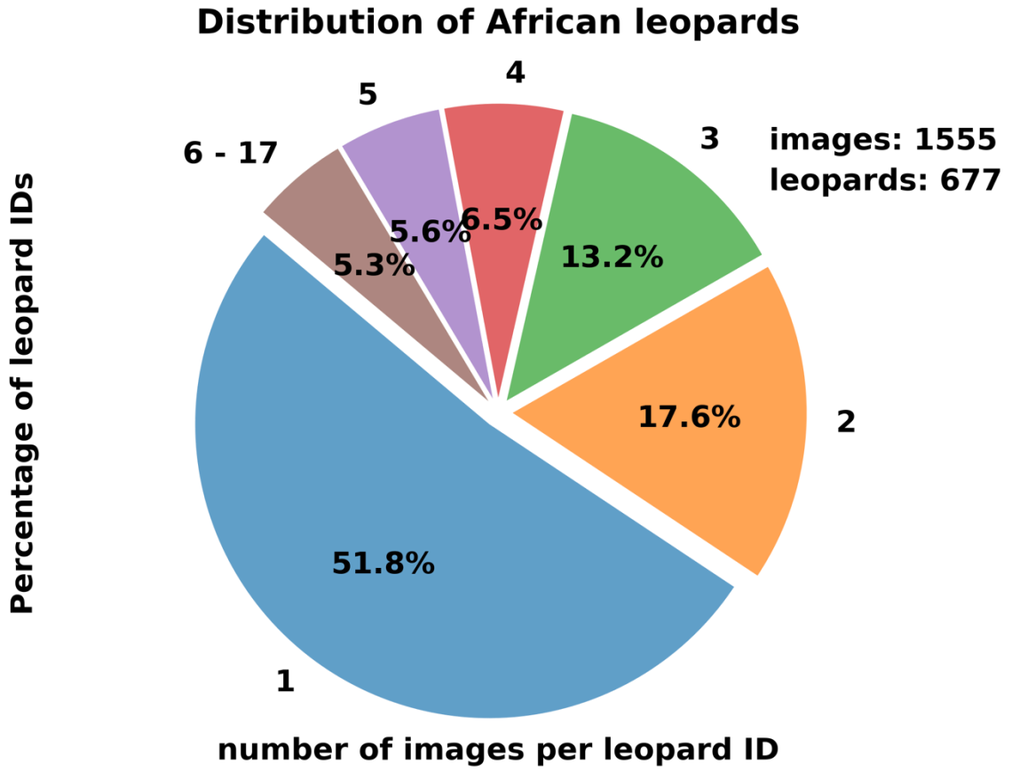
05/22/2025

- Camera traps are automatically triggered by motion in their vicinities
  - Placing along trails that leopard probably visit frequently
  - Activated by moving animals, swaying vegetation, or sudden changes in weather



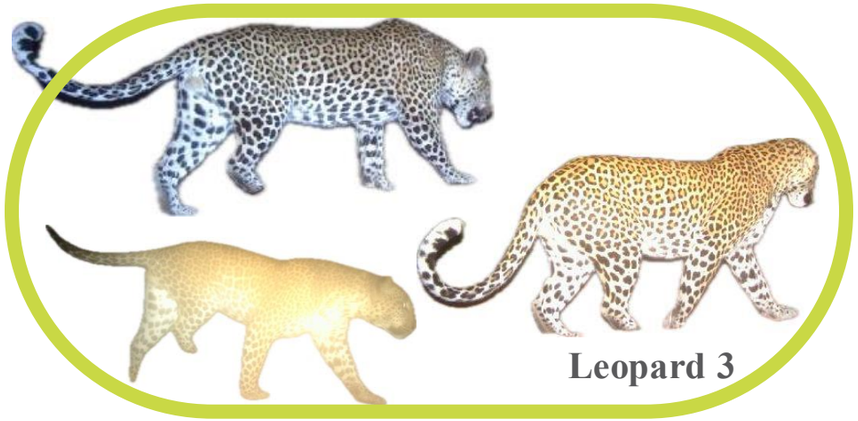
- Existing low-quality camera trap images
  - Overexposure, noise, occlusion, and animals that are only partially visible

- A high individual-to-image ratio
- Only a single image for many leopards

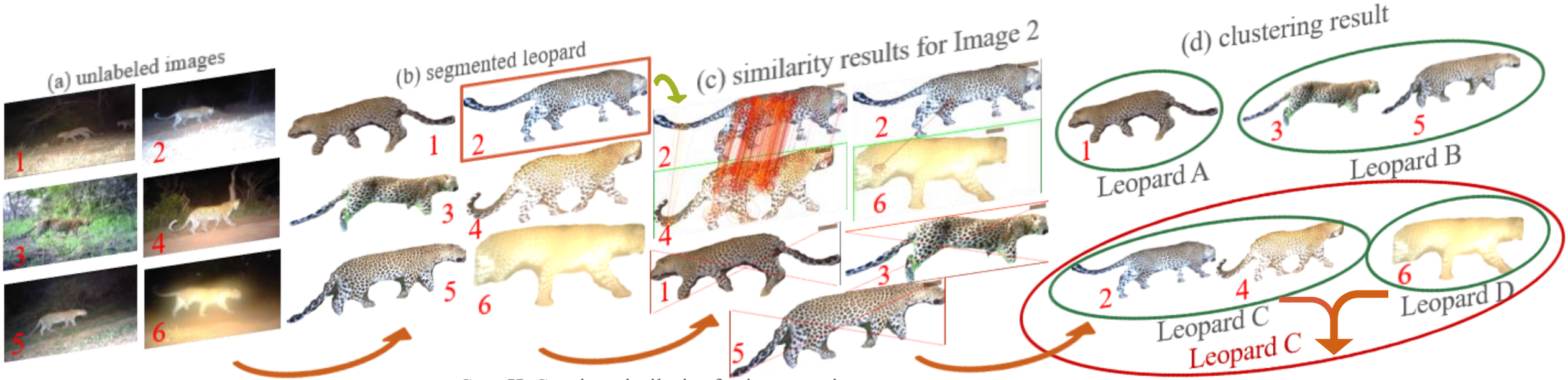


- Identify individual animals
  - Individual re-identification (closed set)
  - New individual migrate to habitat (open-set)
  - **Individual identification (read world)**
    - **Determine the unknown number of *K* individual animals in *N* unlabeled camera-trap images**
    - **Label each image with a specific leopard ID**





- Effective technique for fully automated individual identification algorithm



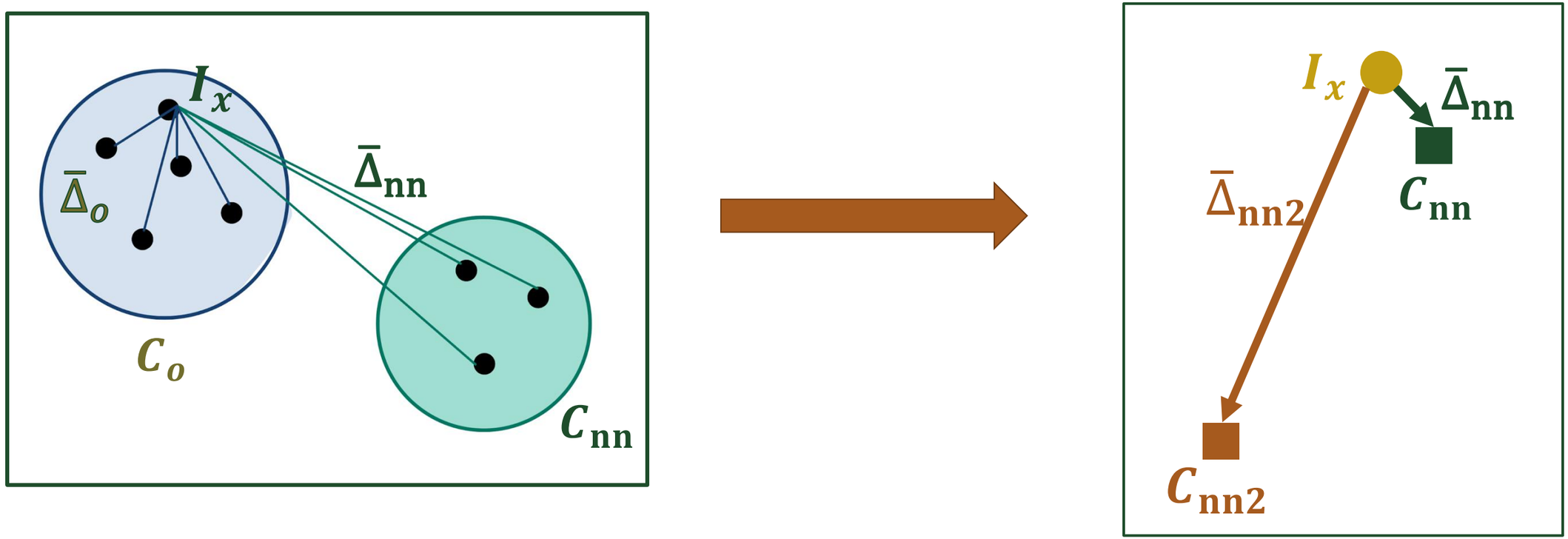

Step I: Segmentation by deep learning (mask R-CNN)

Step II: Scoring similarity for image pairs by traditional image process approach (Hotspotter)

**Step III: Clustering in terms of similarity score matrix (adaptive *k*-medoids++ clustering)**

**Step IV: Verification (merging companion clusters)**

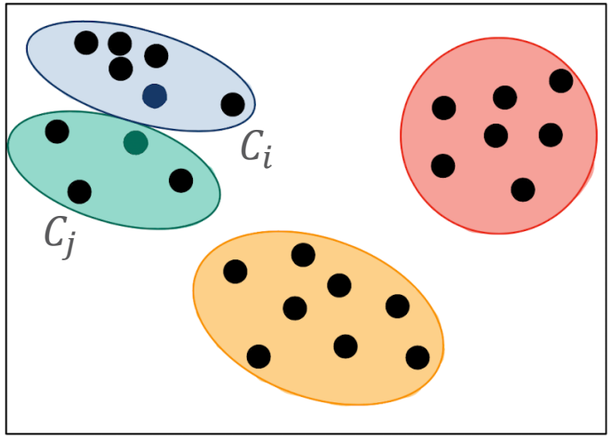
- Expanded definition of the silhouette score of a single-item cluster
  - An internal measure to estimate how fit an image belongs to its own cluster



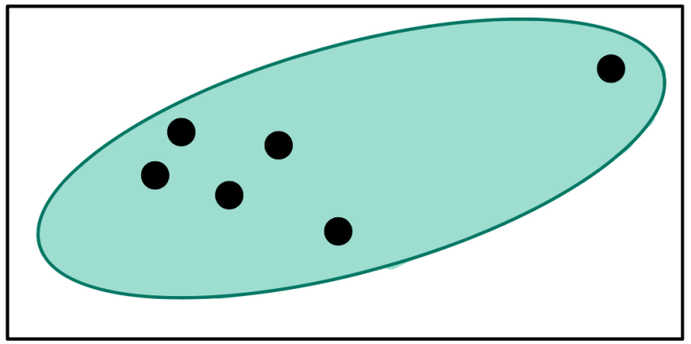
- Novel adaptive $k$-medoids++ clustering algorithm

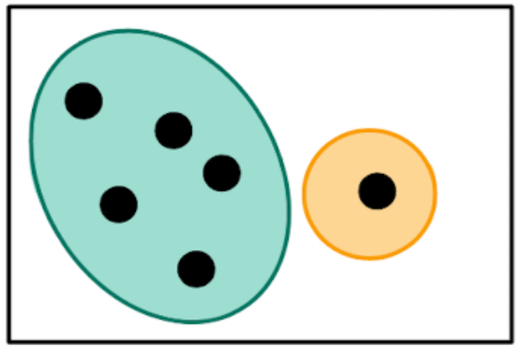
  - Repeat
    - Randomly select $\{M_1, \dots, M_i, \dots, M_k\}$ using the probability distribution with weight factor
    - Execute traditional $k$-medoids++ clustering algorithm
    - Update $s_x$, $\bar{s}$
    - Update the best $\mathcal{C}^*$ with the highest $\bar{s}^*$
    - Update $w_x(j)$
  - Until $\bar{s}^*$ cannot be improved during several iterations

- New post-clustering verification procedure
  - Potentially merge similar clusters



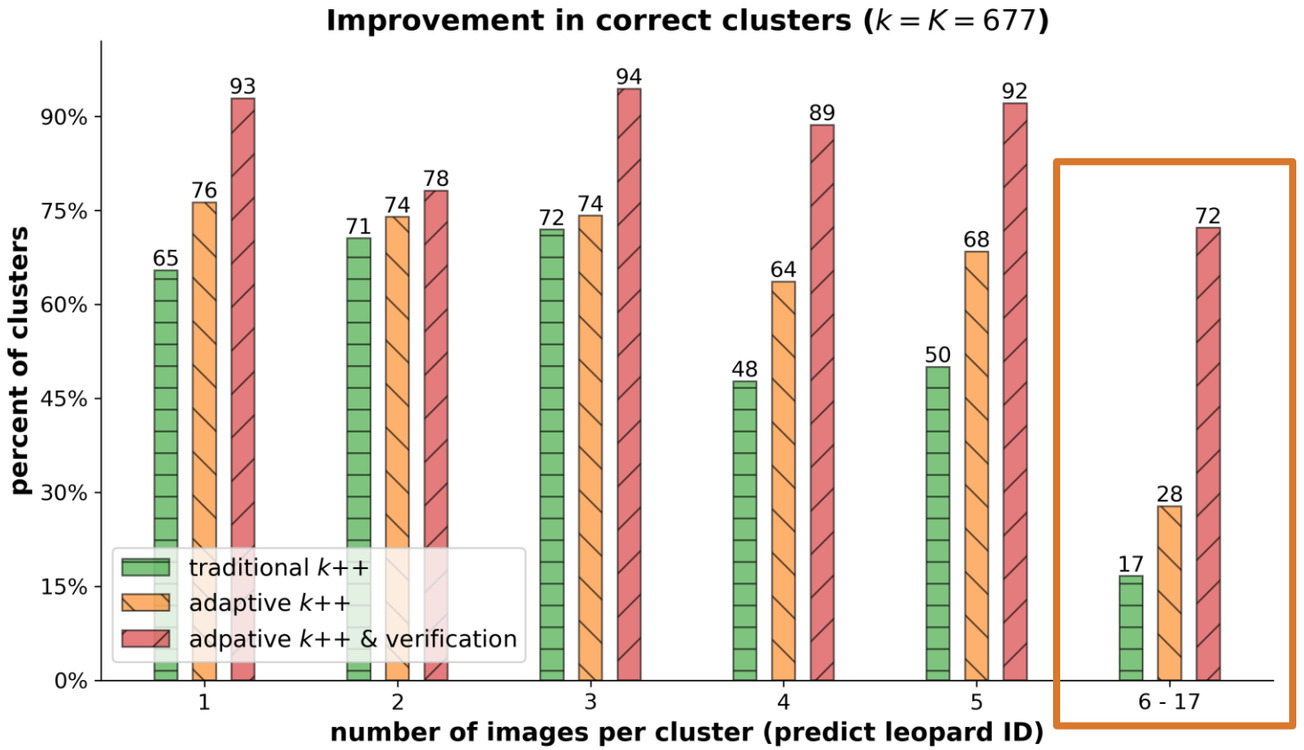

  - Reassign cluster outlier images





| Approach | accuracy | predicted k | correct (images) | partial correct | incorrect |
|---|---|---|---|---|---|
| baseline *k*++ | 0.864 | 793 | 554 (64.4%) | 220 (30.6%) | 19 (5.0%) |
| our adaptive *k*++ | 0.895 | 739 | 566 (70.3%) | 145 (23.3%) | 28 (6.4%) |
| **our adaptive *k*++ &verification** | **0.958** | **718** | **617 (83.8%)** | **91 (14.0%)** | **10 (2.2%)** |

- correct cluster: consist of ALL the images of a single leopard and no other leopard images
- partial correct cluster: consist of SOME images from a single leopard and no other leopard images
- incorrect: NOT a correct partially correct cluster



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# Thank you

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