Machine Learning for Video Tracking of Passengers and Divested Objects at the Checkpoint

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ALERT
AWARENESS AND LOCALIZATION OF EXPLOSIVES-RELATED THREATS

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So What? Who Cares?

- **Space:** Video-based monitoring of passengers and divested items in airports.
  - Correlating Luggage and Specific Passengers (CLASP) Program, ALERT & DHS S&T Apex Screening at Speed Program.

- **Problem:** Machine learning algorithms are effective but unpredictable

- **Solution:** Uncertainty-aware models

- **Results:** Task-specific improvements
  - e.g., segmentation +4% accuracy,
  - gaze estimation +20% accuracy

- **TRL:** 4/5

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What is the CLASP program trying to do?

Automatically identify within the airport security checkpoint:

- The location of passengers and their divested items
- When items are left behind at the checkpoint
- Theft events at the checkpoint
- Bottlenecks within the security checkpoint operation

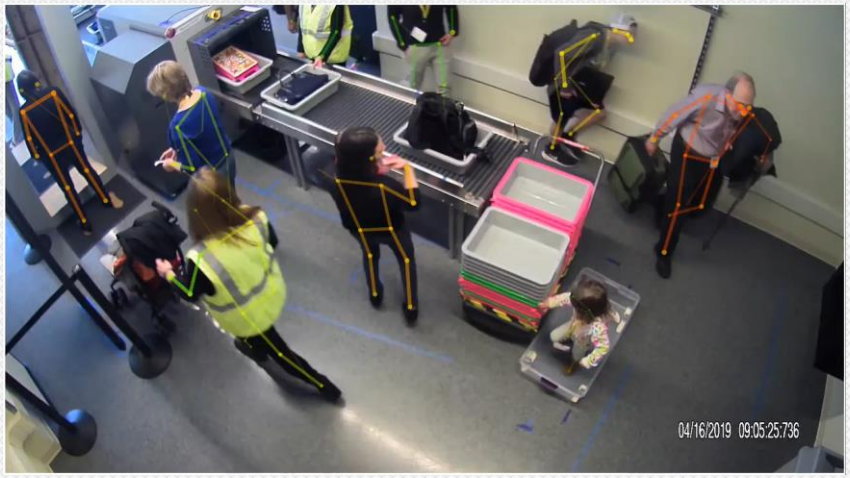
Making the TSA's Job Easier

By maturing algorithms developed under CLASP1, the team strives to make the passenger-baggage tracking capability sufficiently robust so it can **support operational pilots** and support Risk Based Screening in an airport environment.

The CLASP team hopes to **reduce the cognitive load** on Transportation Security Officers (TSOs) at the security checkpoint or command center and reduce operating costs by automating the detection of these events.

Applications of machine learning in CLASP

- Convolutional Pose Machine [1]

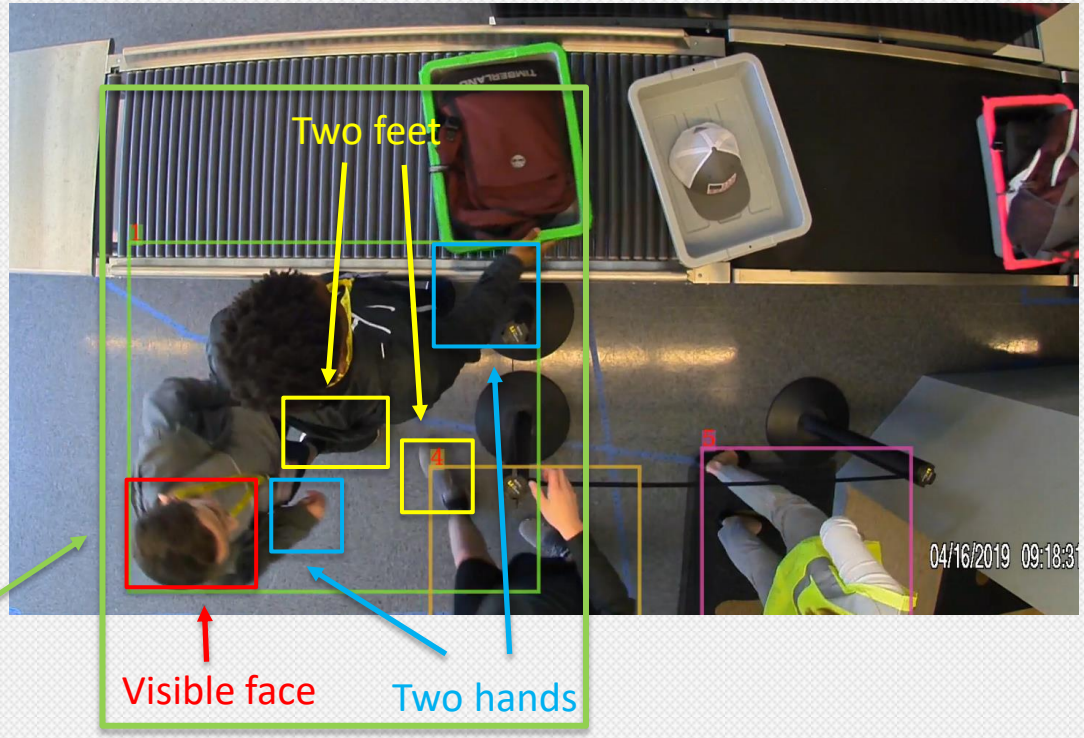


- Mask R-CNN [2]

[1] Shih-En, Ramakrishna, Kanade, Sheikh. "Convolutional pose machines." *IEEE Conference on Computer Vision and Pattern Recognition* 2016
[2] He, Gkioxari, Dollár, Girshick. "Mask R-CNN." *IEEE International Conference On Computer Vision* 2017

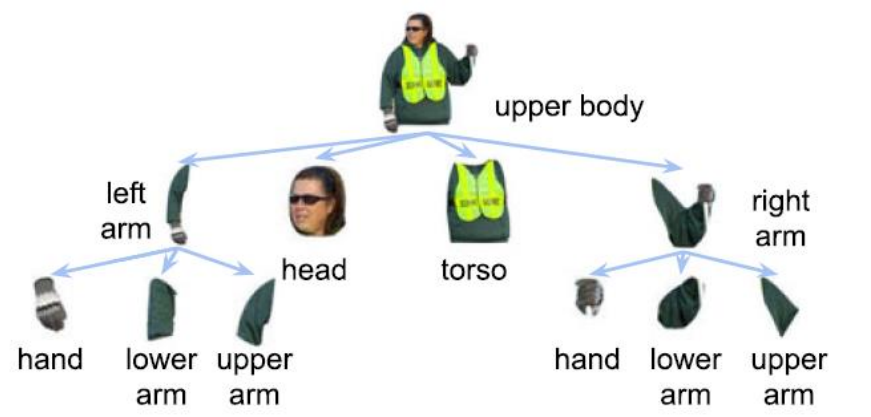
Failure cases of Mask R-CNN

- Compositional models help **explain** failure cases
- They do not help **detect** or **solve** them
- Need mechanisms to estimate network uncertainty



Interpretability of convolutional neural networks

- Image grammars are interpretable [3]



- And can help understand the behavior of CNNs [4]

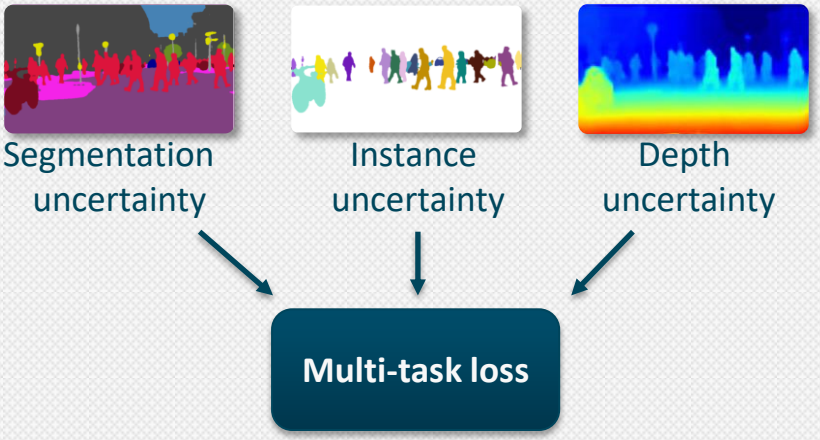
[3] Park, Nie, Zhu "Attribute and-or grammar for joint parsing of human pose, parts and attributes"
IEEE Transactions on Pattern Analysis and Machine Intelligence 2017
[4] Wu, Sun, Li, Song, Li. "Towards Interpretable R-CNN by Unfolding Latent Structures" *arXiv preprint* 2017

One solution to two problems: Uncertainty-aware models

- **Adaptability:** self-supervised, semi-supervised learning, active, reinforcement learning

- 99.3% accuracy in MNIST using 50 labeled samples per class [7]

- **Robustness:** error estimates, outlier detection, resampling, data fusion



- E.g., multi-task learning improves the performance of individuals tasks [6]

[6] Kendall, Gal, Cipolla "Multi-task learning using uncertainty to weigh losses for scene geometry and semantics" *IEEE Conf. on Computer Vision and Pattern Recognition* 2018
[7] Ribeiro, Calivá, Swainson, Gudmundsson, Leontidis, Kollias "Deep Bayesian Self-Training" *Neural Computing and Applications* 2019

Challenges

- Choosing the network architecture
  - Network size, multi-scale processing, fully convolutional, specialization
  - **Sequential models**
  - Effective prior distributions and likelihood models
- Bootstrapping the models
  - Transfer learning strategies
  - **Manual annotation**
- Evaluating the accuracy of the estimated uncertainties
  - How to combine task-specific variances into useful model information
- Reducing computational costs

Thank You

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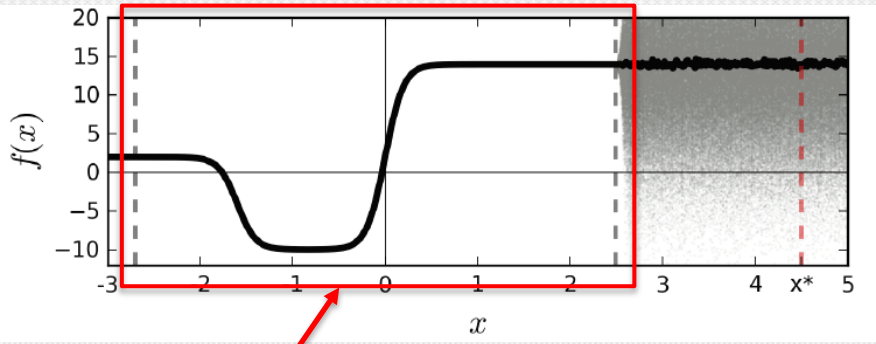
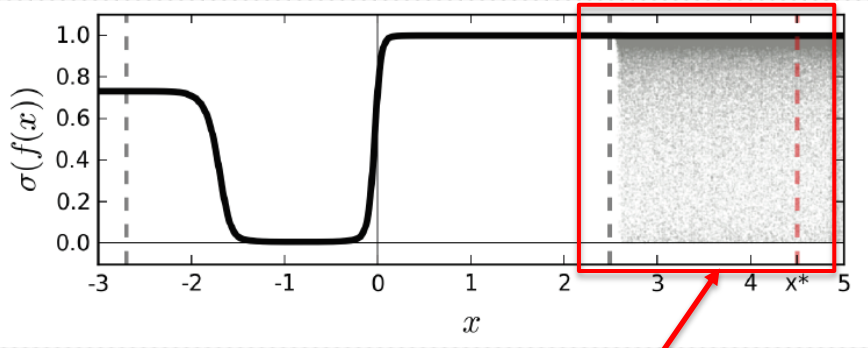
Neural networks don't know what they don't know

- **Network predictions are not confidence estimates** [5]



Training data

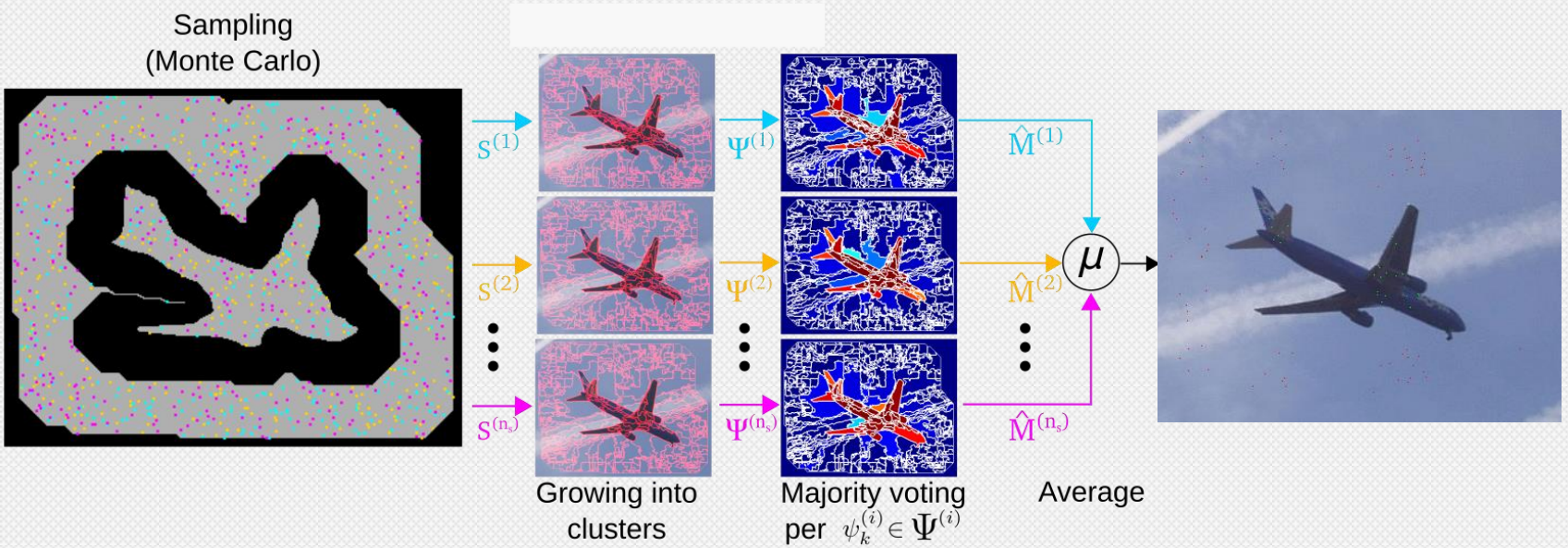


Predictions with unjustified high confidence

[5] Gal, Ghahramani "Dropout as a Bayesian approximation: Representing model uncertainty in deep learning" *International Conference on Machine Learning* 2016

Estimating uncertainty with Monte Carlo sampling

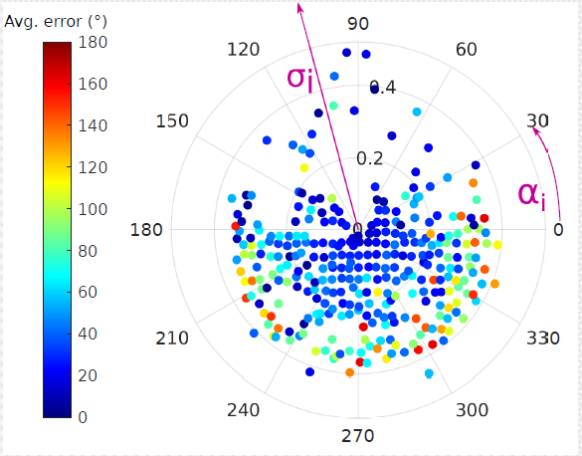
- Use multiple predictions to correct high-confidence mistakes
- E.g., semantic segmentation refinement [8]



[8] Dias, Medeiros "Semantic segmentation refinement by Monte Carlo region growing of high confidence detections" *Asian Conference on Computer Vision* 2018

Uncertainty learning

- Train the network to explicitly predict the uncertainty
- E.g., uncertainty-aware gaze estimation [9]



[9] Dias, Malafronte, Medeiros, Odone "Gaze Estimation for Assisted Living Environments" *IEEE Winter Conference on Applications of Computer Vision* 2019