MSP-DISK: Naturalistic and Diverse In-Vehicle Database for Joint Pose and Seat Belt Detection

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Introduction

- **Dataset**
  - MSP-DISK
    - Diverse in-vehicle seat belt and driver keypoint dataset
- **Light-weight detection model**
  - Two simultaneous tasks
  - Keypoint detection
    - F1-score of 0.773
  - Seat belt segmentation
    - Intersection over union of 27.8%

Outline

1. Significance
2. Related Works
3. Dataset
4. Model Implementation
5. Results
6. *Inspiration* and Future Work

Significance

- **Driver accountability and safety**
  - 3,000 deaths, 300,000 injuries from distracted driving in U.S. in 2020 [1]
- **Driver monitoring system (DMS)**
  - Monitor driver pose/attention/gaze/distraction
  - Safety of driver, passengers, other drivers, pedestrians
- **Dataset**
  - Existing datasets collected in controlled, simulator settings
    - Safety, human subjects
  - Datasets should reflect real-world driving
  - Collect data from driving videos
    - Diverse interiors, subjects, camera position, lighting, etc.

[1] NHTSA, "Distracted driving 2020," National Highway Traffic Safety Administration (NHTSA), Department of Transportation (DOT), Washington, DC, Technical Report DOT HS 813 309, May 2022. [Online]. Available: https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/81330

Related Works

Database	Context	Variety	Pose	Seat belt
MPII [2]	Out-of-vehicle	-	Yes	No
DriPE [3]	In-vehicle	Multi-vehicle	Yes	No
NADS-Net [4]	In-vehicle	Dedicated vehicle	Yes	Yes
Kim *et. al.* [5]	In-vehicle	Dedicated vehicle	Yes	Yes
Drive&Act [6]	In-vehicle	Dedicated vehicle	Yes	Yes
MSP-DISK (ours)	In-vehicle	Multi-vehicle	Yes	Yes

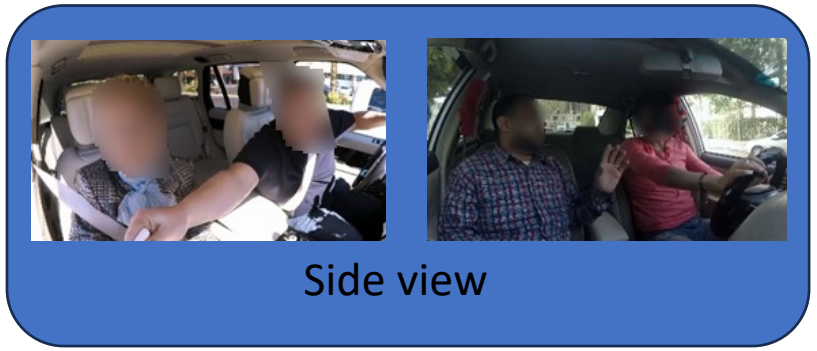
- **Limited in-vehicle datasets**
  - Want human pose and seat belt
  - Occlusion, illumination variations in vehicles
- **Ours expands on diversity**
  - Over 80 unique vehicle interiors
  - Many videos have multiple unique subjects
  - Camera angles

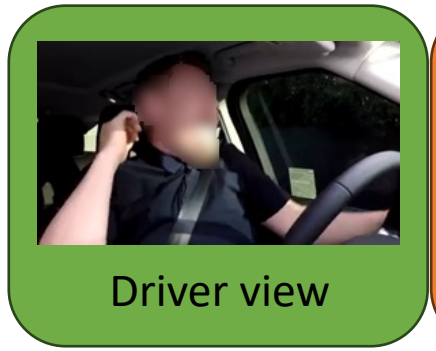
*References on final slide

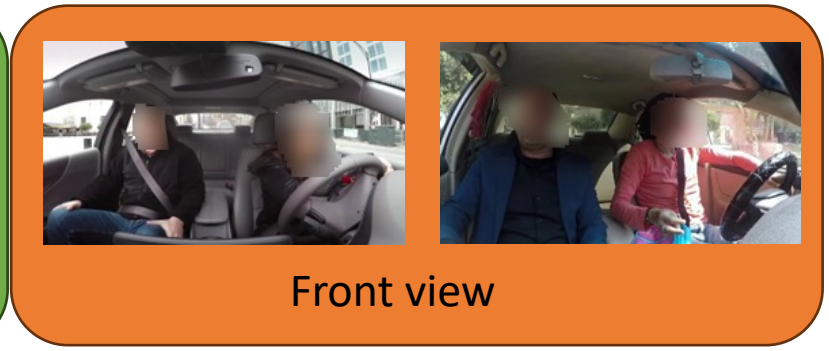
MSP-DISK Dataset – Collection

- **In-vehicle videos**
  - Vlogs, entertainment shows, etc.
- **Cluster by camera angle**
  - Ensure diversity in available angles/scenes
  - Reject frames from scenes outside the vehicle

Partition	Videos	Frames
Train	290	5,038
Development	81	1,095
Test	171	1,571
Total	542	7,704







MSP-DISK Dataset – Keypoint Annotation

- **Improve upon state-of-the-art model performance**
  - Use OpenPose (Cao 2017) [7] for initial keypoint locations
  - Manually adjust incorrect predictions
    - Missed/extra predictions, incorrect locations
  - Reject hidden lower-body keypoints
  - Split into 8 channels
  - Apply Gaussian heatmap centered on each keypoint

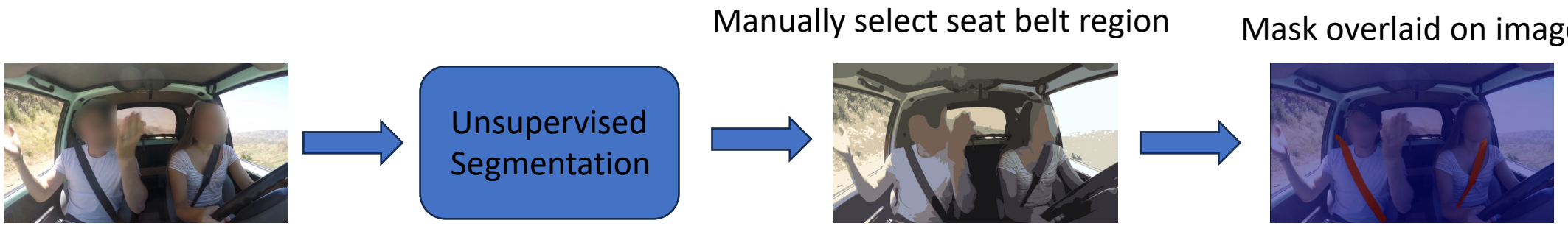
[7] Z. Cao, G. Hidalgo, T. Simon, S. E. Wei, and Y. Sheikh, "OpenPose: Realtime multi-person 2D pose estimation using part affinity fields," IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 43, no. 1, pp. 172–186, January 2021.

Heatmaps overlaid on image

MSP-DISK Dataset – Seat Belt Annotation

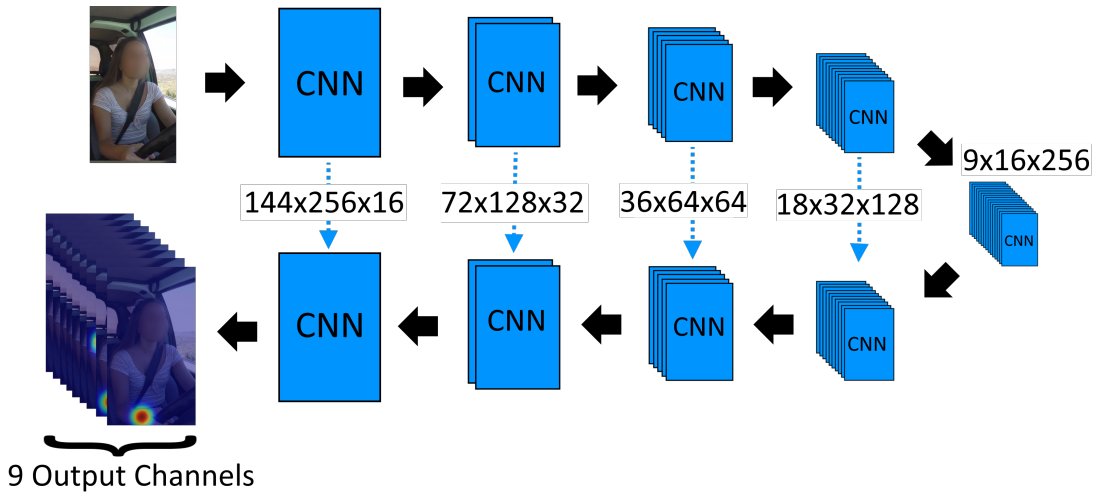
- **Low-cost seat belt segmentation**
  - Perform unsupervised image segmentation (Kanezaki 2018) [8]
    - Group similar colors within image
    - Group shades of seat belt into contiguous region
  - Manually select seat belt region
    - Extract pixel coordinates
  - Use binary mask of seat belt locations

[8] A. Kanezaki, "Unsupervised image segmentation by backpropagation,"
in IEEE International Conference on Acoustics, Speech and Signal
Processing (ICASSP 2018), Calgary, AB, Canada, 2018, April 2018,
pp. 1543–1547.



Lightweight Detection Model

- **U-Net model architecture**
  - Input: 144x256 image cropped per subject
  - Output: 8 keypoint channels + 1 seat belt channel
- **Combination loss function**
  - Weighted L2 loss on keypoint channels
  - Focal loss [9] on seat belt channel
  - Intersection over union loss on all 9 channels



[9] H. Law and J. Deng, "CornerNet: Detecting objects as paired key-points," in European Conference on Computer Vision (ECCV 2018), ser. Lecture Notes in Computer Science, V. Ferrari, M. Hebert, C. Sminchisescu, and Y. Weiss, Eds. Munich, Germany: Springer Berlin Heidelberg, September 2018, vol. 11218, pp. 765–781.

Results

- **F1 metrics**
  - Harmonic mean of precision and recall
  - “Correct” prediction within 20px of ground truth
- **Seat belt**
  - Intersection over union
- **Model parameters**
  - Ours: < 2M parameters
  - OpenPose: < 22M parameters

F1 Prediction Scores

Keypoint	OpenPose [7]	Ours	Ours – with flip augmentation
R Wrist	0.443	0.358	0.459
R Elbow	0.670	0.652	0.743
R Shoulder	0.932	0.911	0.928
L Shoulder	0.937	0.905	0.922
L Elbow	0.688	0.682	0.722
L Wrist	0.431	0.299	0.418
Neck	0.965	0.927	0.938
Head	0.985	0.932	0.937
Average	0.757	0.709	0.773
Seat belt [IoU]		21.7%	27.8%

Conclusion

- **MSP-DISK Dataset**
  - Naturalistic images
  - Diverse, challenging images
  - Keypoint and seat belt detection tasks
- **Lightweight detection model**
  - Trained on MSP-DISK
  - Detects upper-body keypoints and seat belt

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MSP-DISK Dataset GitHub

MSP-DISK Code GitHub

References

[1] NHTSA, "Distracted driving 2020," National Highway Traffic Safety Administration (NHTSA), Department of Transportation (DOT), Washington, DC, Technical Report DOT HS 813 309, May 2022. [Online]. Available: https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/81330

[2] M. Andriluka, L. Pishchulin, P. Gehler, and B. Schiele, "2D human pose estimation: New benchmark and state of the art analysis," in IEEE Conference on Computer Vision and Pattern Recognition (CVPR 2014), Columbus, OH, USA, June 2014, pp. 3686–369

[3] R. Guesdon, C. Crispim-Junior, and L. Tougne, "DriPE: A dataset for human pose estimation in real-world driving settings," in IEEE/CVF International Conference on Computer Vision Workshops (ICCVW 2021), Montreal, BC, Canada, April 2021, pp. 2865–28

[4] S. Chun, N. Ghalehjegh, J. Choi, C. Schwarz, J. Gaspar, D. McGehee, and S. Baek, "NADS-Net: A nimble architecture for driver and seat belt detection via convolutional neural networks," in IEEE/CVF International Conference on Computer Vision Workshop (ICCVW 2019), Seoul, Republic of Korea, October 2019, pp. 2413–242

[5] G. Kim, H. Kim, J. Kihoon Kim, S.-S. Cho, Y.-H. Park, and S.-J. Kang, "Integrated in-vehicle monitoring system using 3D human pose estimation and seat belt segmentation," in AAAI 2022 workshop AI for Transportation, Vancouver, BC, Canada, February-March 2022, pp. 1–8.

[6] M. Martin, A. Roitberg, M. Haurilet, M. Horne, S. Reiß, M. Voit, and R. Stiefelhagen, "Drive&act: A multi-modal dataset for fine-grained driver behavior recognition in autonomous vehicles," in IEEE/CVF International Conference on Computer Vision (ICCV 2019), Seoul, Republic of Korea, October - November 2019, pp. 2801–28

[7] Z. Cao, G. Hidalgo, T. Simon, S. E. Wei, and Y. Sheikh, "OpenPose: Realtime multi-person 2D pose estimation using part affinity fields," IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 43, no. 1, pp. 172–186, January 2021.

[8] A. Kanezaki, "Unsupervised image segmentation by backpropagation," in IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP 2018), Calgary, AB, Canada, 2018, April 2018, pp. 1543–1547.

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