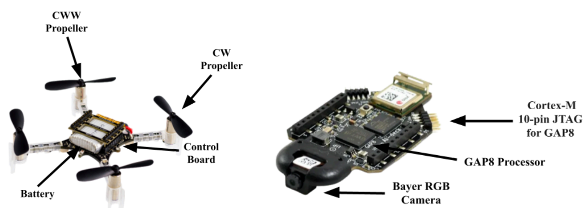
Optimizing Edge Robotics with YOLO, SORT, and TinyMPC for Enhanced Object Tracking and Control

Vidushi Jindal[1,2], Aliya Tang[2], Brian Plancher[2]
1: Rutgers University, 2: Barnard College, Columbia University

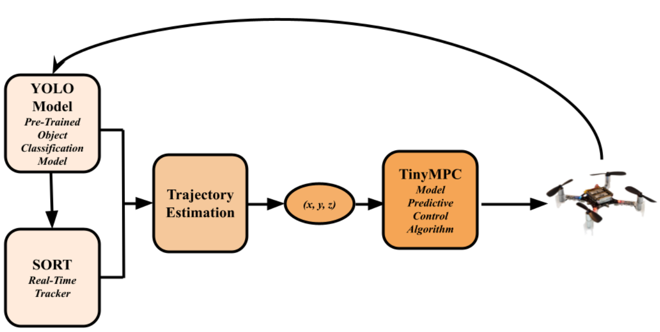
Introduction: Our research focuses on integrating YOLO for object detection, SORT for object tracking, and TinyMPC for model predictive control to enhance the efficiency and accuracy of robotic systems. Using the CrazyFlie 2.1, a small and low-cost robot equipped with the AI Deck and GAP8 IoT processor, we aim to improve real-time obstacle avoidance and dynamic trajectory tracking. This integration allows for better handling of complex trajectories and actuator constraints, promoting the use of affordable technology in robotics.



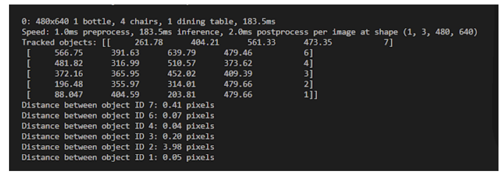
Methods: Our workflow is divided into three sections: object detection, tracking, and trajectory estimation. We utilized pre-trained YOLO models for real-time object detection and classification, followed by Simple Online and Realtime Tracking (SORT) for object tracking. Finally, we incorporated a trajectory estimation algorithm to compute object movement in the 2D plane of the image.

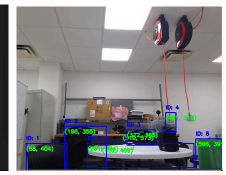
For object detection and classification, we tested our algorithm on both YOLO models to perform real-time object detection and classification, sending the data for bounding boxes to the tracker. The SORT algorithm processes data from the YOLO model and tracks the detected objects. The tracked positions are then used to compute the desired trajectory, incorporating a trajectory estimation algorithm that measures the Euclidean distance between objects, providing measurements of the object's movement in the 2D plane of the image.

Our approach involves integrating a MPC with a vision model to enhance dynamic collision resistance optimization. TinyMPC shows superior recovery performance and tracks complex trajectories while considering actuator limits. By combining TinyMPC with vision input, we aim to enhance real-time obstacle avoidance through improved tracking and detection.



Results: Our results demonstrate a real-time object detection and tracking system capable of accurately identifying and localizing objects. Each detected object is assigned a unique ID, and its position is tracked across consecutive frames. The system's output includes information about the detected objects, their coordinates, and distances between the frames. The system provides information on preprocessing, inference, and post-processing times for each frame. The results indicate that the trajectory estimation algorithm performs effectively in tracking objects within the image frame.





Conclusions: Integrating computer vision algorithms into low-computing platforms like the CrazyFlie is feasible but presents hardware challenges. We successfully implemented object detection and classification, real-time tracking, and 2D trajectory estimation. While we effectively retrieved 2D trajectory coordinates, our initial attempts to retrieve 3D trajectories using monocular depth estimation were not successful. In the future, we aim to implement 3D trajectory tracking by exploring advanced depth estimation techniques. Future work includes completing the integration of our vision algorithm with TinyMPC, deploying the integrated system onto the CrazyFlie, and enhancing the trajectory estimation to 3D.

This research contributes to the development of affordable and accessible robotic platforms, benefiting various communities and advancing the field of robotics. Potential applications include search and rescue operations in disaster-stricken areas, agricultural monitoring and management, environmental monitoring, and educational tools for teaching robotics.

References:

A. Alavilli, K. Nguyen, S. Schoedel, B. Plancher, and Z. Manchester, "TinyMPC: Model-predictive control on resource-constrained microcontrollers," arXiv preprint arXiv:2310.16985, 2023.

A. Farooq, S. Z. Nain Zukhraf, S. Shafi, M. Kamal and N. Chumuang, "Vision-Based Navigation for a Small-Sized Drone: A Simple AI Strategy at IMAV'22," 2024 IEEE International Conference on Cybernetics and Innovations (ICCI), Chonburi, Thailand, 2024, pp. 1-5, doi: 10.1109/ICCI60780.2024.10532299.

B. Ke, A. Obukhov, S. Huang, N. Metzger, R. C. Daudt, and K. Schindler, "Repurposing diffusion-based image generators for monocular depth estimation," in Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition, 2024, pp. 9492-9502.

J. Redmon, S. Divvala, R. Girshick and A. Farhadi, "You Only Look Once: Unified, Real-Time Object Detection," 2016 IEEE Conference on Computer Vision and Pattern Recognition (CVPR), Las Vegas, NV, USA, 2016, pp. 779-788, doi: 10.1109/CVPR.2016.91.

Alex Bewley, Zongyuan Ge, Lionel Ott, Fabio Ramos, Ben Upcroft. "Simple Online and Realtime Tracking," 2016 IEEE Conference on Computer Vision and Pattern Recognition (CVPR),

Acknowledgements: I would like to thank Dr. Brian Plancher, the A^{2}R Lab, and the Columbia-Amazon SURE program for their continued support throughout the entire research program.