Position based camera-2D LiDAR fusion and person following for Mobile robots

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1 Introduction



Person following is vital for robotic wheelchairs, for applications like caregiving, transport.

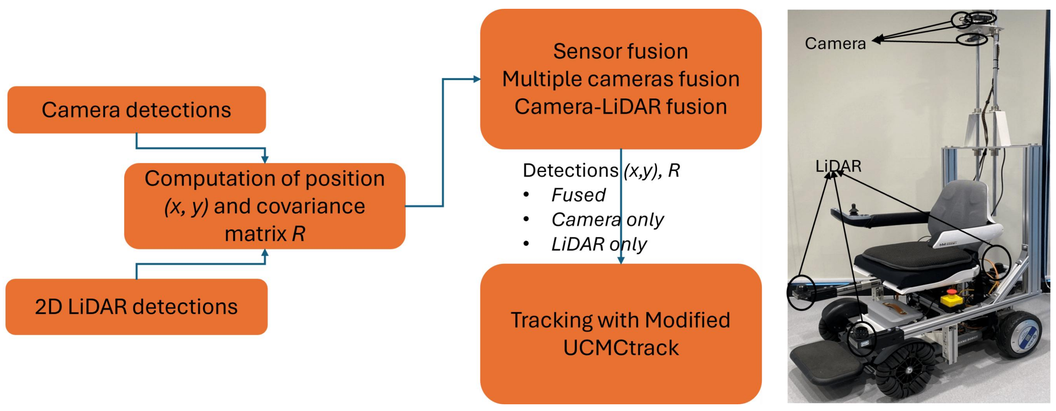
- Traditional 2D LiDAR tracking methods suffer from **restricted fields of view and high false positives (FP) due to environmental clutter.**
- **No proper study to evaluate position and image based tracking for person following use case.**
- The paper i**ntroduces a position-based person tracking framework that integrates multi-sensor fusion to enhance the reliability and accuracy of person following for robotic wheelchair.**
- The system was thoroughly **tested on a wheelchair prototype** and demonstrated reliable multi-angle tracking performance, improved accuracy, reduced false positives, and enhanced ID stability compared to baseline approaches.

Tracking approach	Approach	Effectiveness in person following
Position based	Fuse features from RGB-D and LiDAR.	Untested
Image based	Deep learning to match person appearance	Tested

2 Approach

Our approach utilizes a position-based person tracking framework that integrates multi-sensor fusion of RGBD cameras and 2D LiDAR to enhance the reliability and accuracy of person following in mobile robots. The following key components outline the methodology:

1. **Novel Sensor Fusion Algorithm**:- to effectively fuse data from multiple sensors that enables consistent tracking, mitigating issues like false positives from environmental artifacts.
2. **Detection and Tracking Framework**:- Utilizing a modified UCMCtrack [1] algorithm to processes fused sensor data to initialize and manage tracks based on a combination of visual and spatial information.
3. **Track Management**:- to maintain list of active tracks, linking Kalman filter-based positions with detected IDs to enhance tracking stability.



3 Experiments

Dataset

Created a custom dataset to assess the proposed position-based tracking framework in person following for mobile robots. Recorded in a university environment, the dataset includes:

- Single individual scenarios where the robot follows one person.
- Multiple individual instances with several people to test tracking in crowded situations.
- Crowded environment scenarios with obstacles and multiple individuals.

The wheelchair robot was operated manually using joystick to accurately capture the person-following use-case.

Ground Truth Annotation

Ground truth bounding boxes were manually annotated for each individual in the recordings. A total of approximately 382 seconds of data was collected, ensuring a diverse coverage for robust evaluation.

Baseline

Compared to position-based LiDAR tracking [2] and image based OCSort [3] and HybridSORT [4]

Evaluation Metrics

We employed the HOTA (Higher Order Tracking Accuracy) metric to evaluate ID Association, and false positive rate to measure the frequency of incorrect detections.

4 Results

Method	HOTA	DetA	AssA	FP tracks
Proposed	**74.753**	75.537	**73.977**	**0**
LiDAR tracking [2]	73.643	**76.039**	71.323	23
OCSort [3]	45.012	68.23	29.778	-
HybridSORT [4]	44.566	47.765	42.787	-

Our position-based person tracking framework showed improvements over baseline methods in the following key areas:

1. **Better overall tracking and ID retention shown by higher HOTA Score**
2. **Superior maintenance of ID association as shown by Association Accuracy (AssA) score**
3. **Lesser False Positives**
4. **Consistent ID retention and reduced ID switching in crowded environments**

Overall, these results validate our approach's efficacy for reliable and accurate person following in mobile robotics applications.

5 Conclusion & Future Work

This study presents a position-based person tracking framework for robotic wheelchairs that effectively fuses data from RGB-D cameras and 2D LiDAR. Our results show significant improvements in tracking performance, including enhanced ID retention and reduced false positives compared to traditional methods.

Future work will focus on expanding our dataset to include diverse real-world scenarios, enhancing tracking robustness in various environments. We also aim to integrate advanced machine learning techniques for improved detection accuracy and explore real-time processing capabilities to facilitate smoother interactions between robotic wheelchairs and users.

References

[1] K. Yi, K. Luo, X. Luo, J. Huang, H. Wu, R. Hu, and W. Hao, "UCMCTrack: Multi-Object Tracking with Uniform Camera Motion Compensation," AAAI Conf. on Artificial Intelligence, vol. 38, no. 7, Mar. 2024
[2] A. Leigh, J. Pineau, N. Olmedo, and H. Zhang, "Person tracking and following with 2d laser scanners," in ICRA, 2015.
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[4] M. Yang, G. Han, B. Yan, W. Zhang, J. Qi, H. Lu, and D. Wang, "Hybrid-sort: Weak cues matter for online multi-object tracking," arXiv:2308.00783, 2023.

Llink to paper:

Link to demo video: