Robot Wheelchair Convoys for Assistive Human Transportation

Helio Perroni Filho, Mohammad Akhavan,
Jayant Varma, Sarah Kamoun, James Elder

INTRODUCTION & MOTIVATION

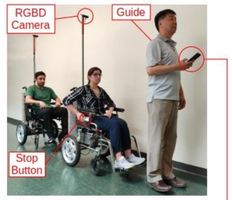
- Airport wheelchair services
  - Support for customers with impaired mobility
  - Labor-intensive – one guide per wheelchair

- Alternative: fully autonomous wheelchairs
  - Expensive hardware
  - Increased safety risks
  - Need for customer instruction

- Compromise: semi-autonomous wheelchair convoy

OBJECTIVES

- Convoy of semi-autonomous wheelchairs
  - First wheelchair follows human guide
  - Second wheelchair follows first wheelchair, third follows second, etc.

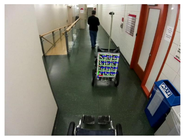


- Single guide manages multiple wheelchairs
- Convoy controlled through mobile device
- Wheelchairs autonomously navigate to keep distance fro leader, avoid obstacles etc.

METHODS

- Guide tracking
  - FeatureSORT-like [1] tracking
  - YOLO11 [2] for person detection
  - OSNet [3] for person ReID

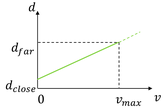
- Wheelchair tracking
  - ArUco [4] boards for wheelchair identification, localization



- Leader following
  - Compute linear speed v from target position, speed

$$v_{chair} = v_{target} + k(d_{target} - d_{goal})$$

$$d_{goal} = v_{target}\frac{d_{far} - d_{close}}{v_{max}} + d_{close}$$

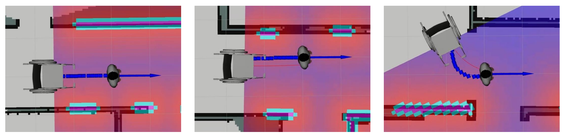


  - Optimize [5] arc of curvature $c = r^{-1}$ to minimize:
    - Distance from target track $[(x_1, y_1), \ldots, (x_n, y_n)]$
    - Obstacle proximity $o(x, y)\ \epsilon[0,1]$

$$\sum_{i=1}^{n}\begin{cases}(y_i - \tau_i)^2 + o(x_i, \tau_i)w_o & \text{if } \tau_i = \tau(x_i, c) \in \mathbb{R} \\ \tau_\theta + w_o & \text{otherwise}\end{cases}$$

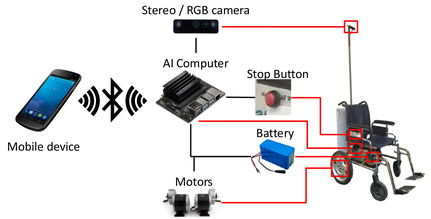
$$\tau(x_i, c) = \begin{cases}0 & \text{if } c = 0 \\ c^{-1} - \text{sgn}(c)\sqrt{c^{-2} - x_i^2} & \text{otherwise}\end{cases}$$

  - Compute angular speed $\omega = cv$

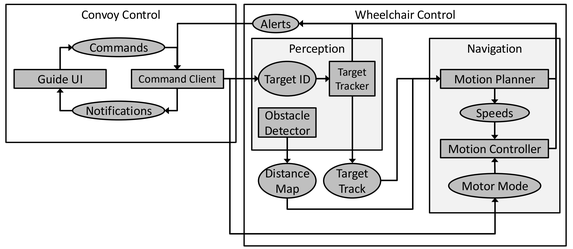


IMPLEMENTATION

- Hardware



- Software



RESULTS

- Successful tests with one and two wheelchairs
  - Indoors
  - Outdoors
  - Varying light conditions

CONCLUSIONS

- AirChair is a semi-autonomous wheelchair convoy system
- Wheelchairs rely on guide to lead them to destination
- Otherwise, they are responsible for own motion, including obstacle avoidance
- Tests in a variety of environments demonstrate system's feasibility
- Further tests, improvements planned

REFERENCES

1. Hashempoor, Hamidreza, Rosemary Koikara, and Yu Dong Hwang. "FeatureSORT: Essential Features for Effective Tracking." *arXiv preprint arXiv:2407.04249* (2024).
2. Khanam, Rahima, and Muhammad Hussain. "Yolov11: An overview of the key architectural enhancements." *arXiv preprint arXiv:2410.17725* (2024).
3. Zhou, K., Yang, Y., Cavallaro, A., & Xiang, T. (2019). Omni-scale feature learning for person re-identification. In *Proceedings of the IEEE/CVF international conference on computer vision* (pp. 3702-3712).
4. Jurado, S. G., Salinas, R. M., Cuevas, F. M., & Jiménez, M. M. (2014). Automatic generation and detection of highly reliable fiducial markers under occlusion. *Pattern Recognition*, *47*(6), 2280-2292.
5. Nelder, J. A., & Mead, R. (1965). A simplex method for function minimization. *The computer journal*, *7*(4), 308-313.