

Motivation

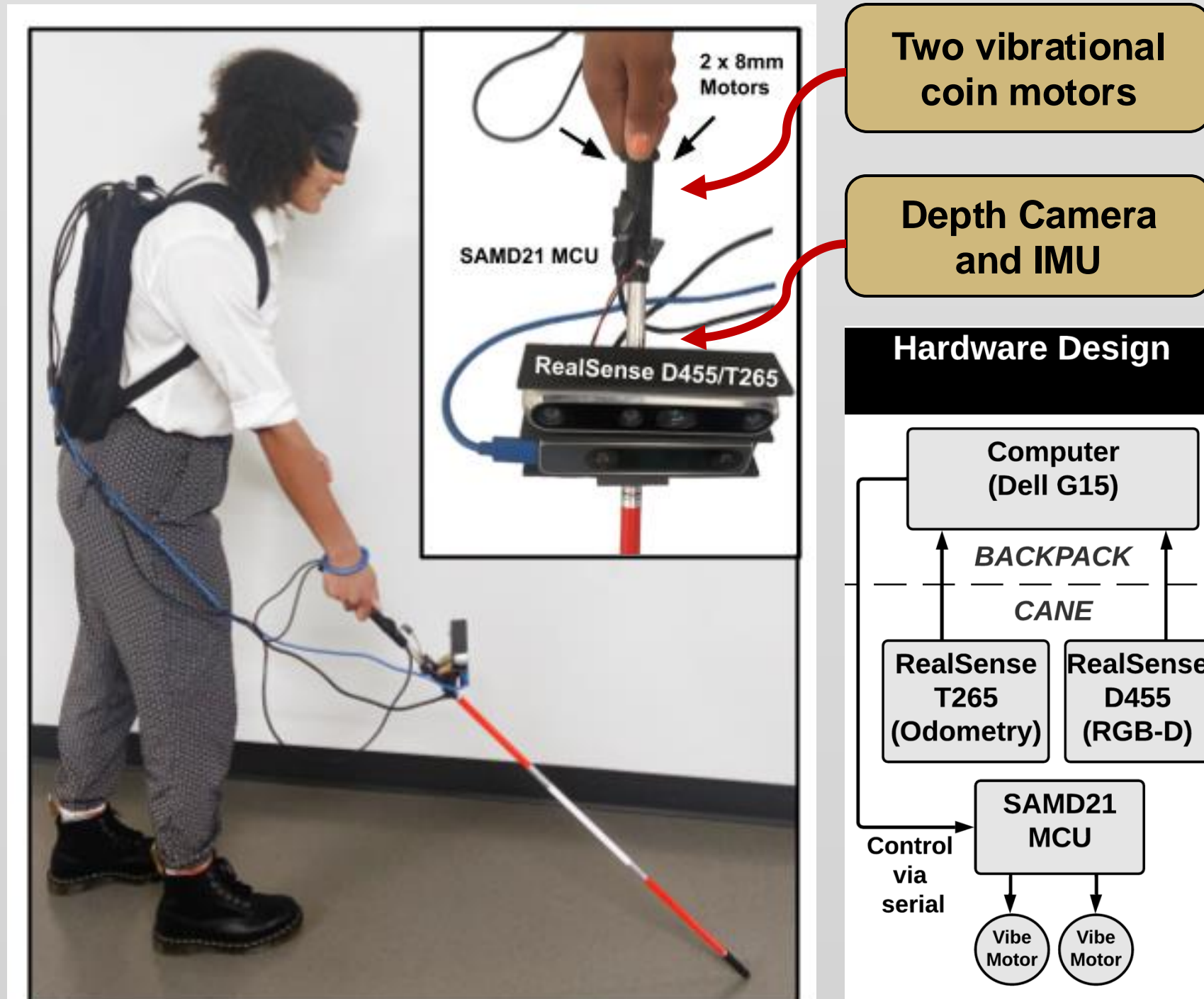
Limitations of common mobility aids :

- Service dogs can cost upwards of \$50,000 to train and incur \$1,200 on average in annual care costs.
- Cane cannot find empty seats in unknown public places.

Motivation :

- Wang et al. showed that **finding seats in crowded public places is an important independent mobility task** for blind and visually impaired (BVI) people [1].
- Staats and Groot showed that **people prefer to seat themselves in a way that optimizes privacy and intimacy** [2].

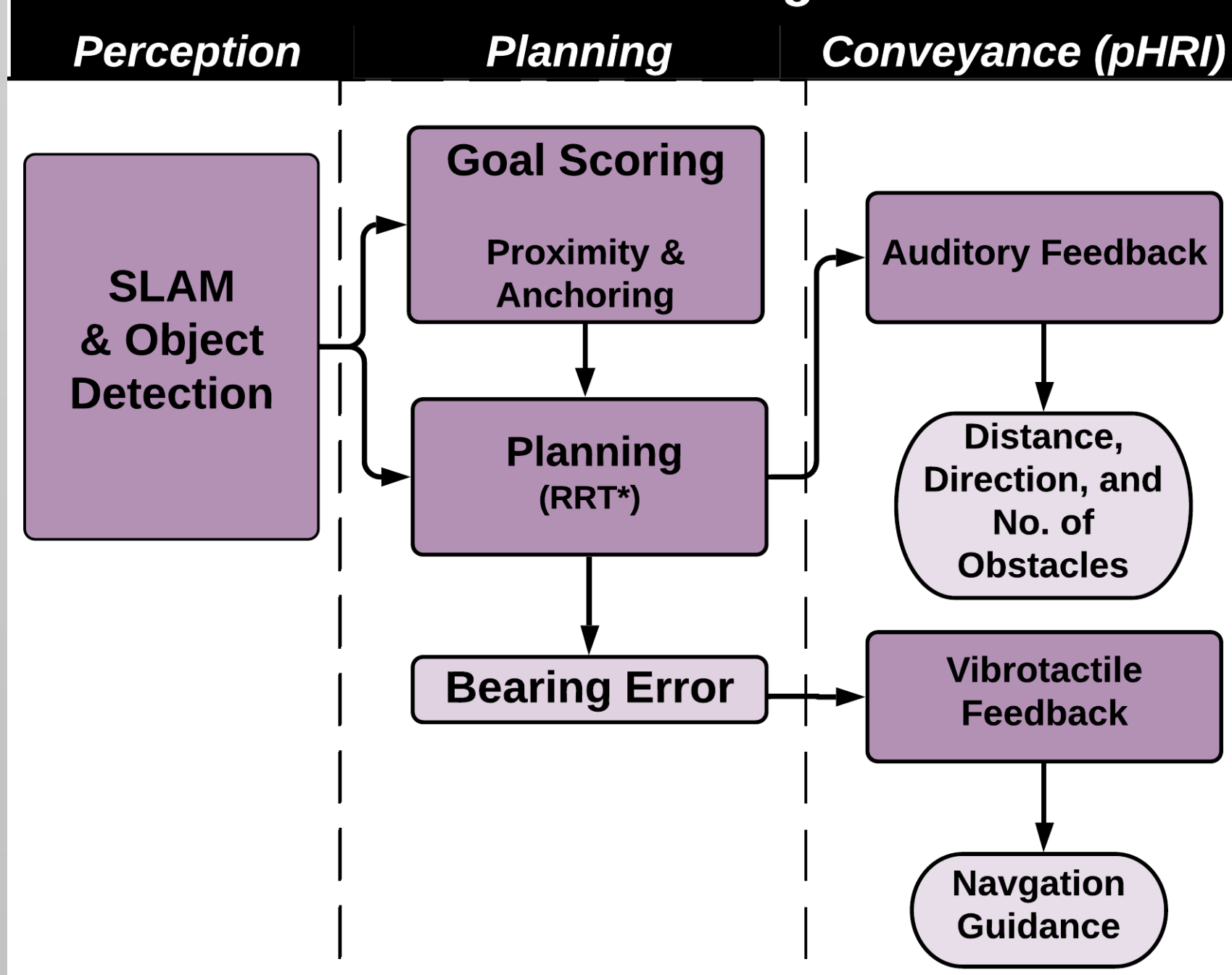
System Design



Design Considerations :

- The cane should be able to function as regular cane and gather collision-based feedback from taps. .
- Vibration motors should be collocated & perceptible through one fingertip [3].

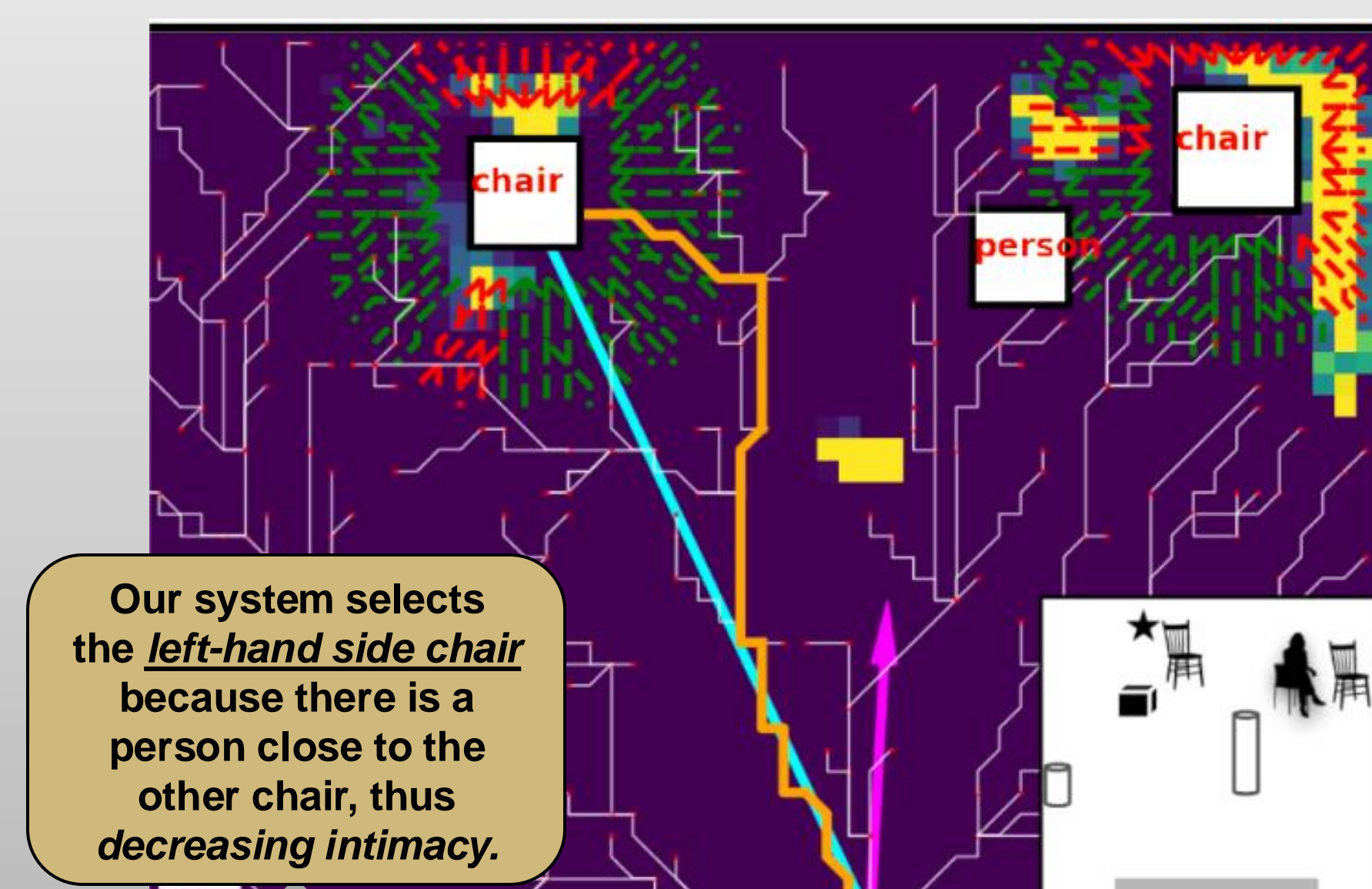
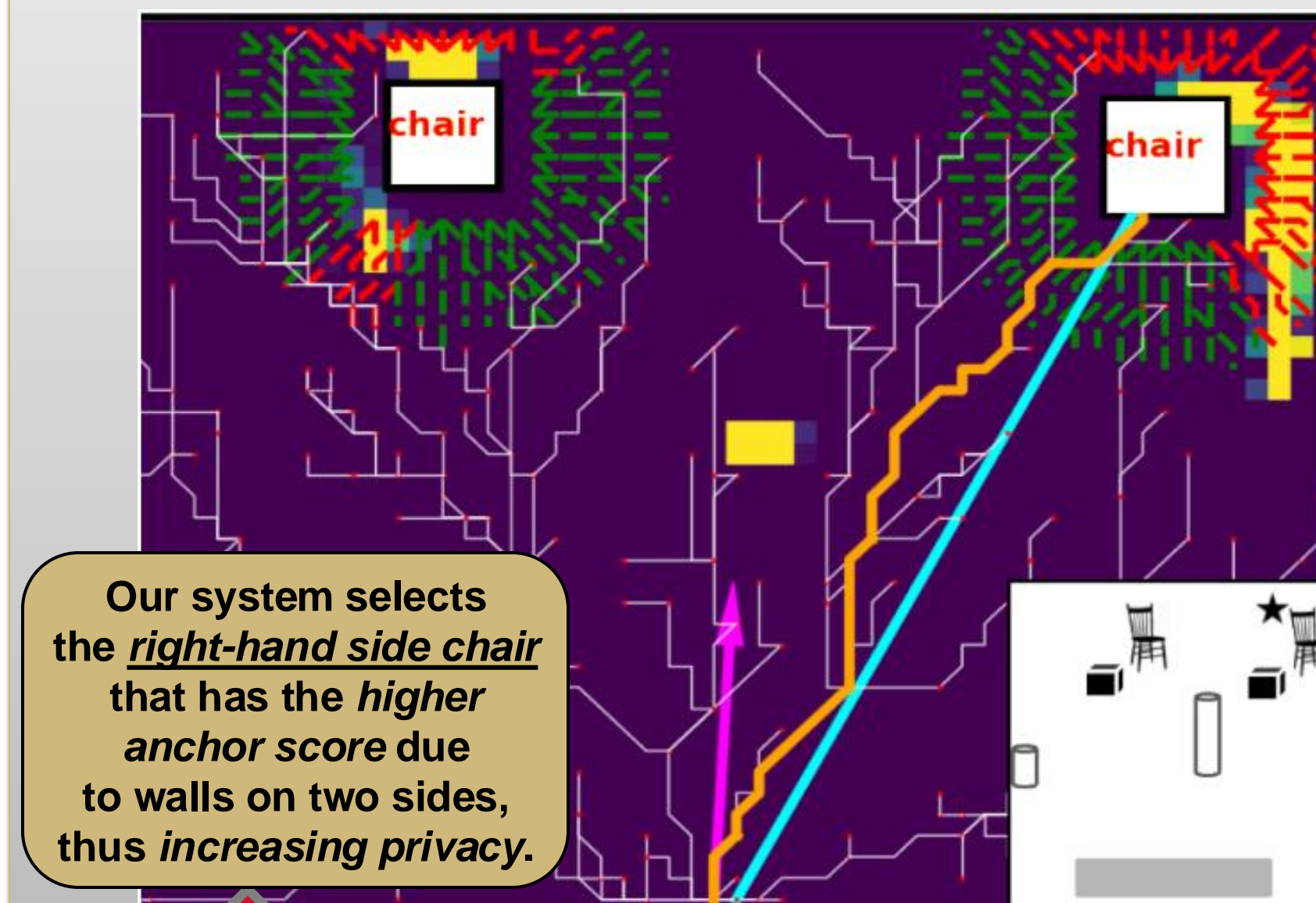
Software Design



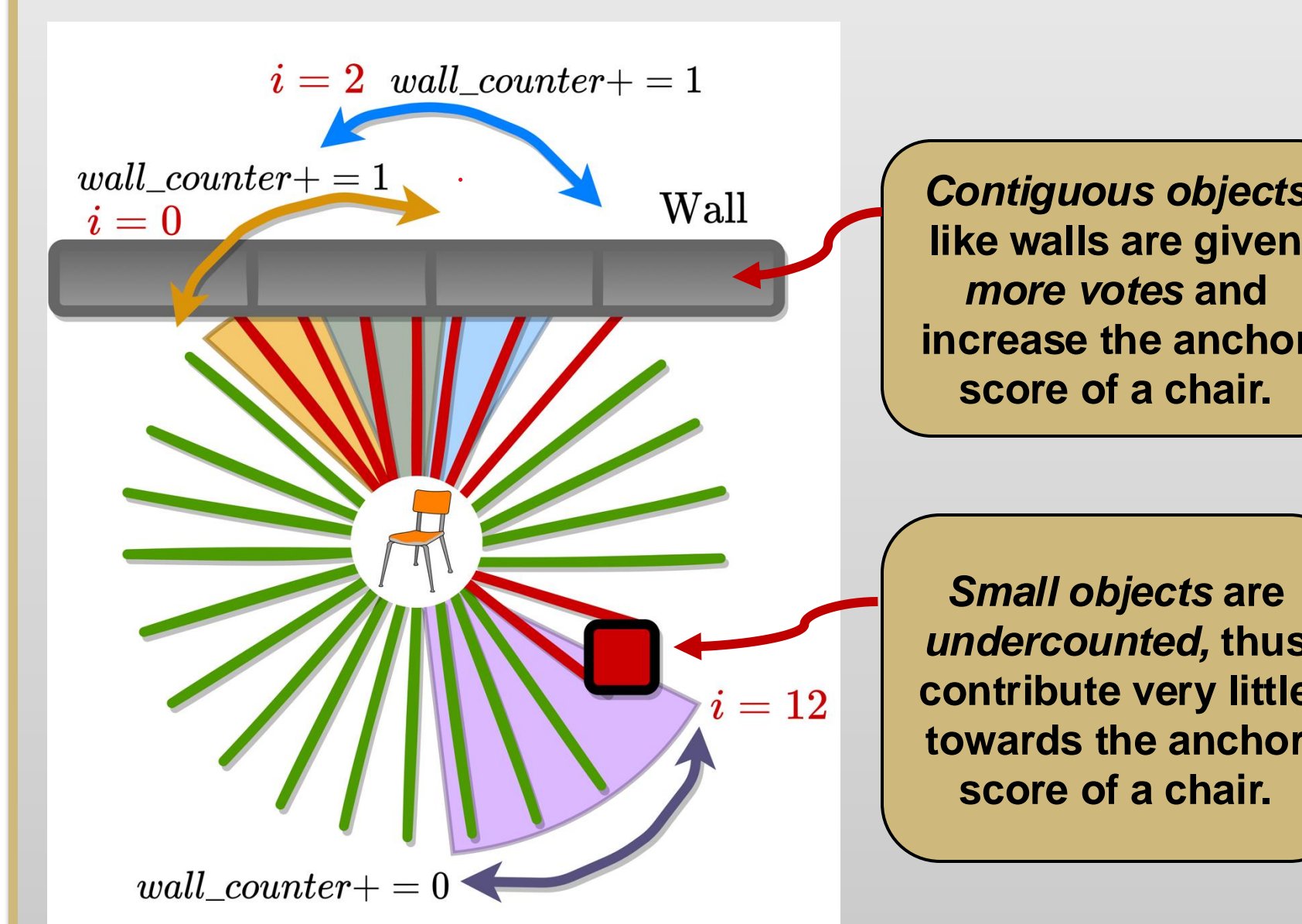
Perception :

- A SLAM algorithm creates a 2D occupancy grid using the RGB-D camera & the IMU while handling arbitrary tilts.
- We use detectron2 and Mask-RCNN for object detection.
- Next, we utilize an Extended Kalman Filter to model object positions as 2D Gaussians.

Goal Scoring and Planning on real-world data

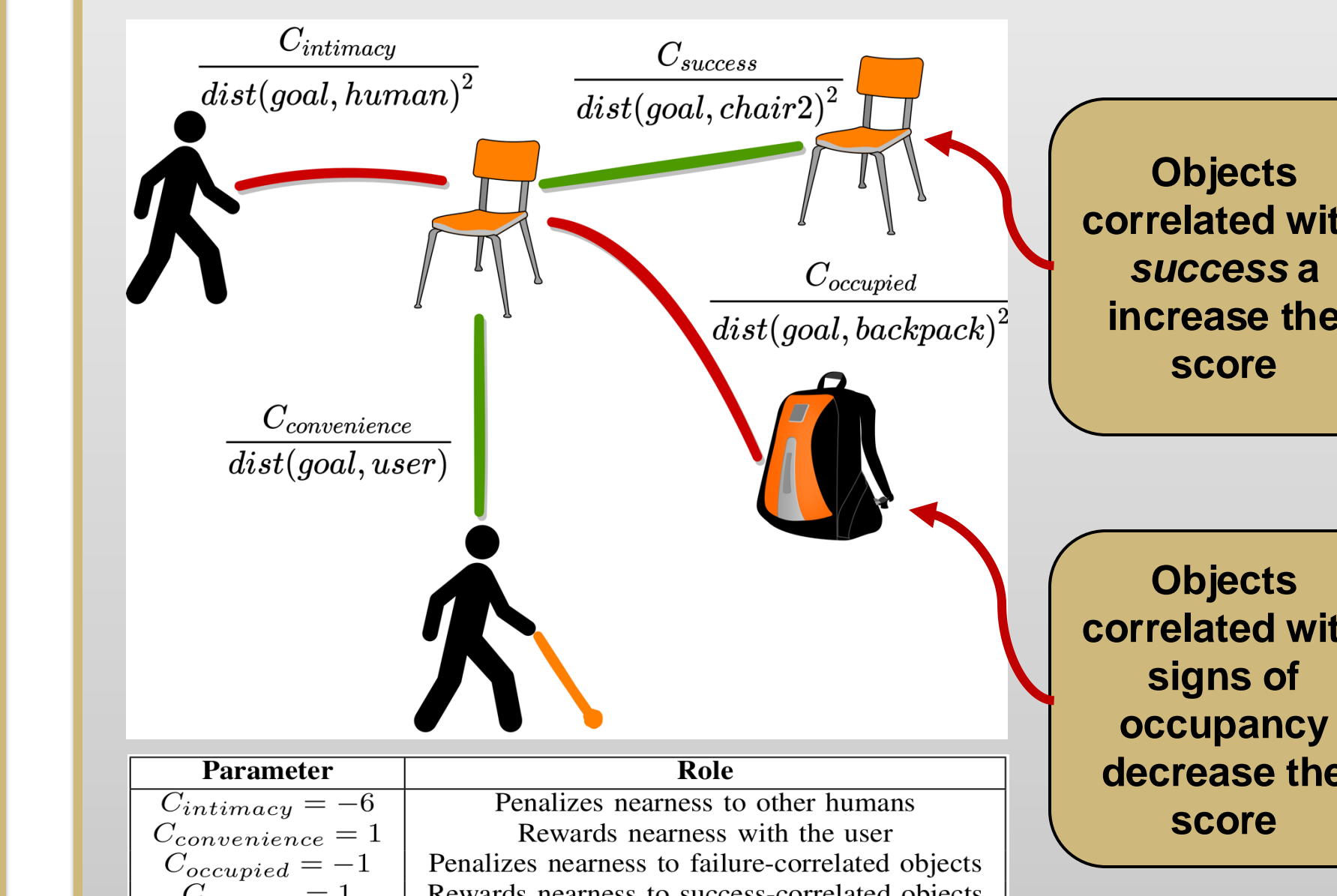


Anchor Score



- Anchor scores are calculated using a sliding window to track object-intersection density with radially cast rays.
- Here windows at $i=0$, $i=2$ get sufficient object-intersecting rays' density whereas window at $i=12$ does not, causing it to not contribute to the anchor score.

Proximity Score

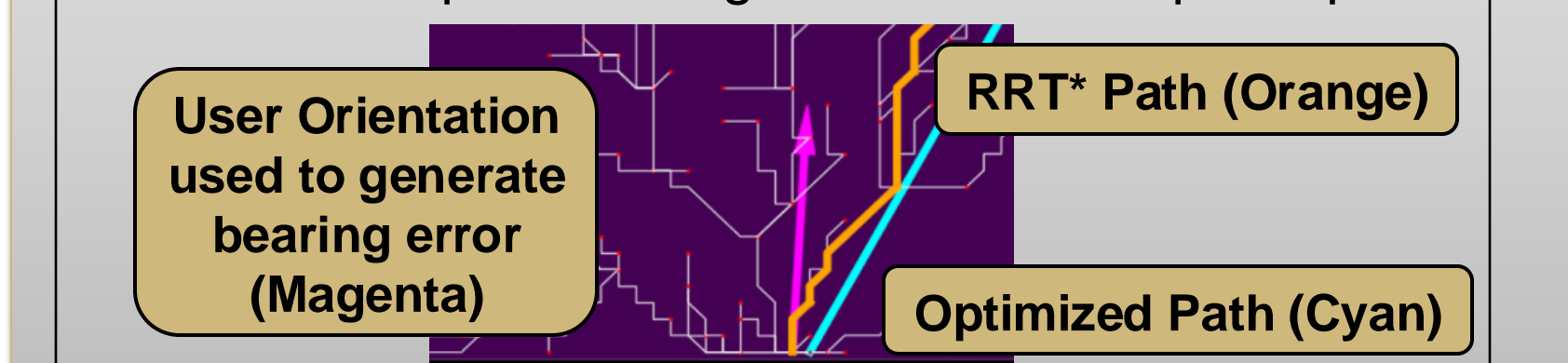


- A chair's proximity score is affected by its relative position with respect to other objects, humans and the user.
- We add the scores shown by the green lines and subtract the ones shown by the red.

Path planning and Plan Conveyance

Path Planning :

- We use RRT* to find a path towards the goal.
- The dark space on the real-world data visualization show free space and lighter shows occupied space.



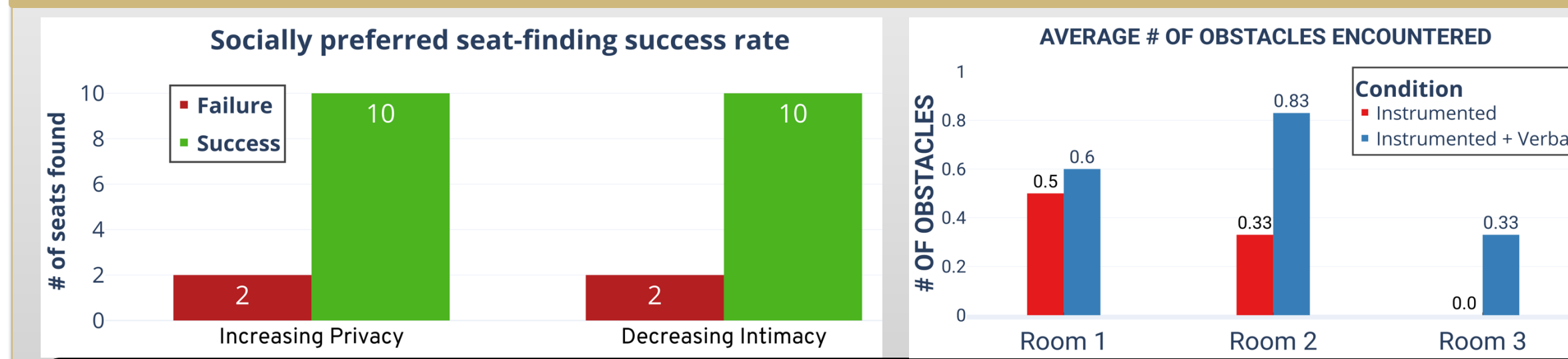
Plan Conveyance :

- **Verbal goal overview:** We generate a semantic description of the goal's relative location with the following template:

"{Goal Object} found about {} meters away in the {} o'clock direction"
- **Vibrotactile guidance:** Bearing error is encoded into two distinct haptic animation [4] patterns on each motor (left and right), creating five possible codes for conveyance:

hard-right, soft-right, straight/no animation, soft-left, and hard-left

Pilot Results



- The users had **83.3% success rate** at finding more socially-preferred seats.
- Even though the rooms had obstacles and walls, the users often were able to avoid collisions.

Experiment: A total of six blindfolded users navigated through six scenarios done over three different room layouts to find a chair.

- Moreover, the users reported **positive user experience** (Following are for verbal enabled).
- **Confidence in navigation** : 4.83 ± 0.41
 - **Confidence in finding the goal** : 4.5 ± 0.84
 - **Verbal overview's helpfulness** : 4.67 ± 0.82

References: [1] H.-C. Wang, R. K. Katzschmann, S. Teng, B. Araki, L. Giarré, and D. Rus, "Enabling independent navigation for visually impaired people through a wearable vision-based feedback system," in 2017 IEEE International Conference on Robotics and Automation (ICRA), 2017, pp. 6533–6540.
 [2] H. Staats and P. Groot, "Seat choice in a crowded café: Effects of eye contact, distance, and anchoring," *Frontiers in Psychology*, vol. 10, p. 331, 2019.
 [3] R. W. Cholewiak, "The perception of tactile distance: Influences of body site, space, and time," *Perception*, vol. 28, no. 7, pp. 851–875, 1999, PMID: 10664778.
 [4] Williams, Michele A., et al. "just let the cane hit it" how the blind and sighted see navigation differently." *Proceedings of the 16th international ACM SIGACCESS conference on Computers & accessibility*. 2014.