Design of a Sensory Augmentation Walker with a Skin Stretch Feedback Handle

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Mobility aids such as cane, crutch and walker are widely used to enhance balance and to prevent falls

- In 2015, the population aged 65 and above represented approximately 8.5% of the global population and is projected to double by 2050
- Mobility aids provide partial weight support and somatosensory feedback from the environment
- Robotic canes or walkers equipped with additional sensors and actuators have been developed to improve the physical and cognitive capabilities

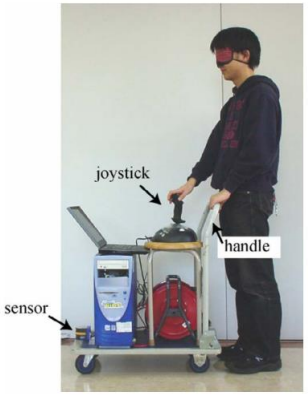
Standard walker

Front-wheeled walker

Rollator

Falls are the most commonly reported walker-related accidents

Walkmate; Shi et al. 2010 [1]



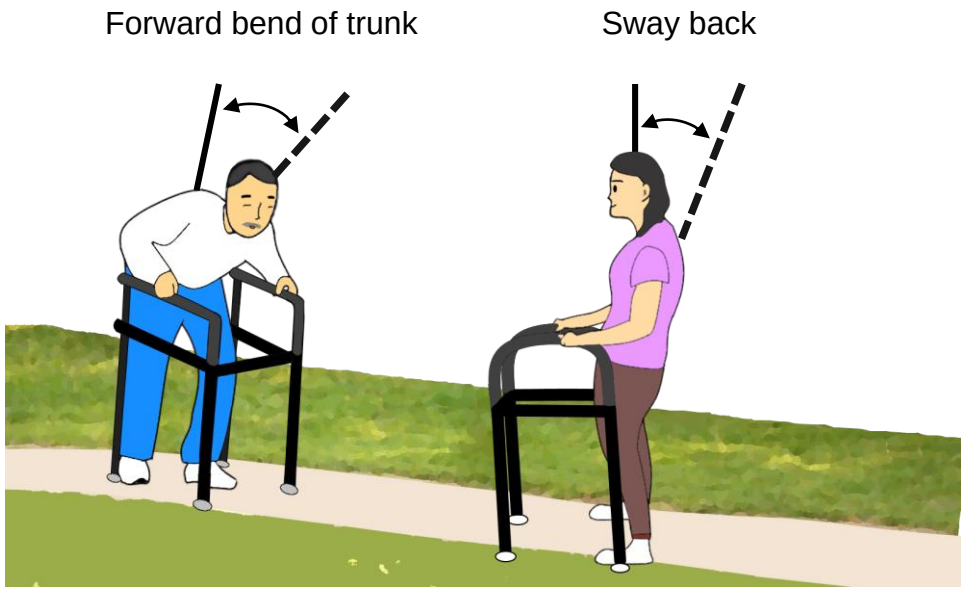
Hashimoto et al. 2006 [2]

ASBGo walker; Martins et al. 2014 [3]

- Detection of users' intents
- Navigation
- Obstacle avoidance
- Additional sensory feedback

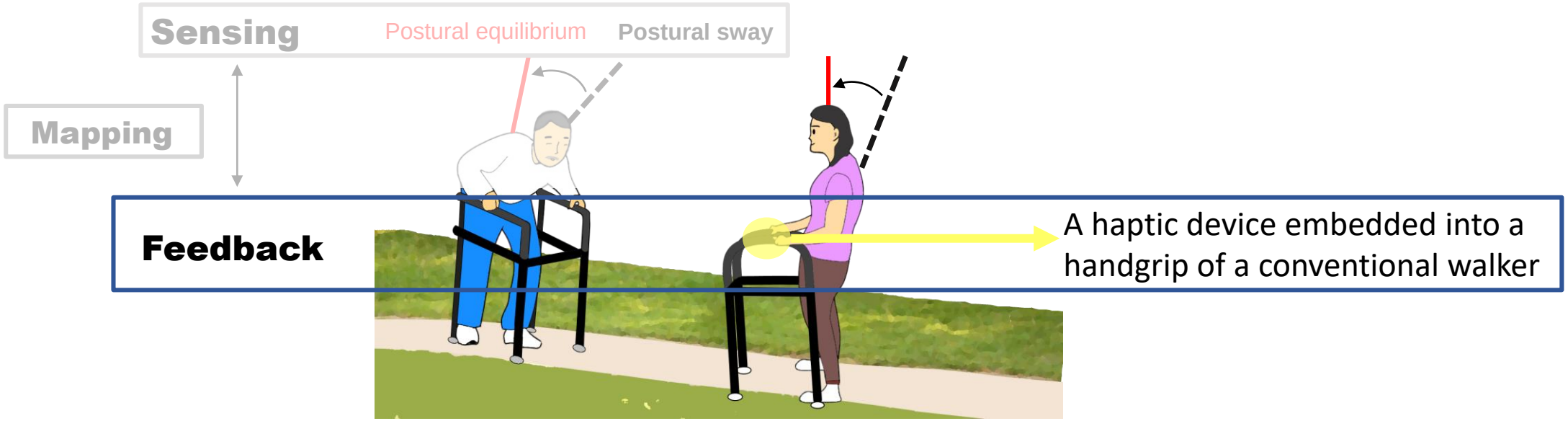
A fall may still occur due to lack of attention or impaired sense of balance

- Few systems evaluate the risk of fall or provide real-time balance feedback



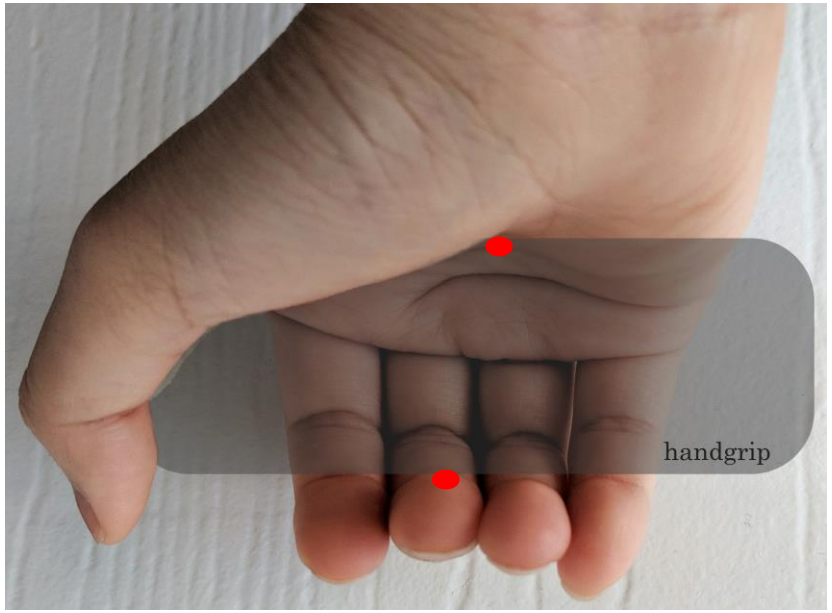
We propose a new functionality that **monitors users' real-time balance performance and provides this information to the user** as a means of improving the postural stability

Sensory augmentation walker that provide balance feedback in A/P direction through a haptic device

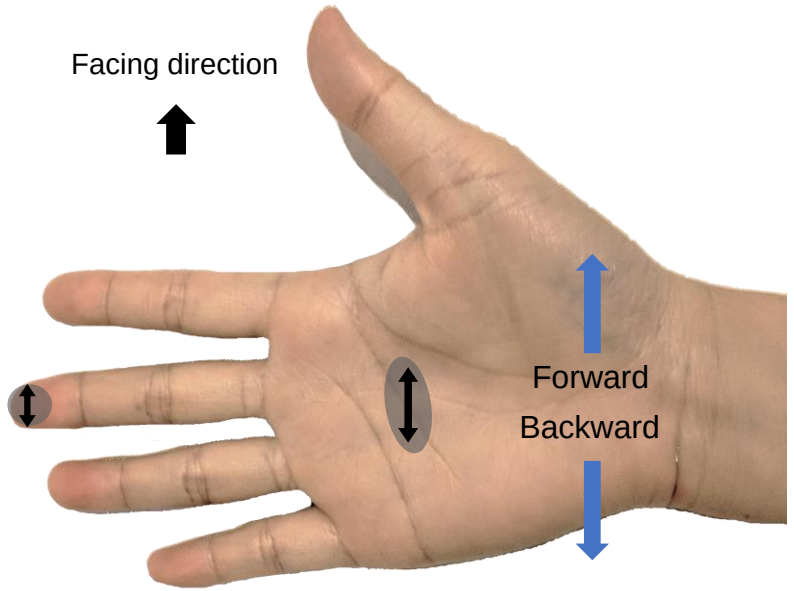


The objective is to *evaluate how intuitive are the directional cues delivered via a handheld device and to compare the performance of the skin sites for perceiving the directional cues.*

Design consideration

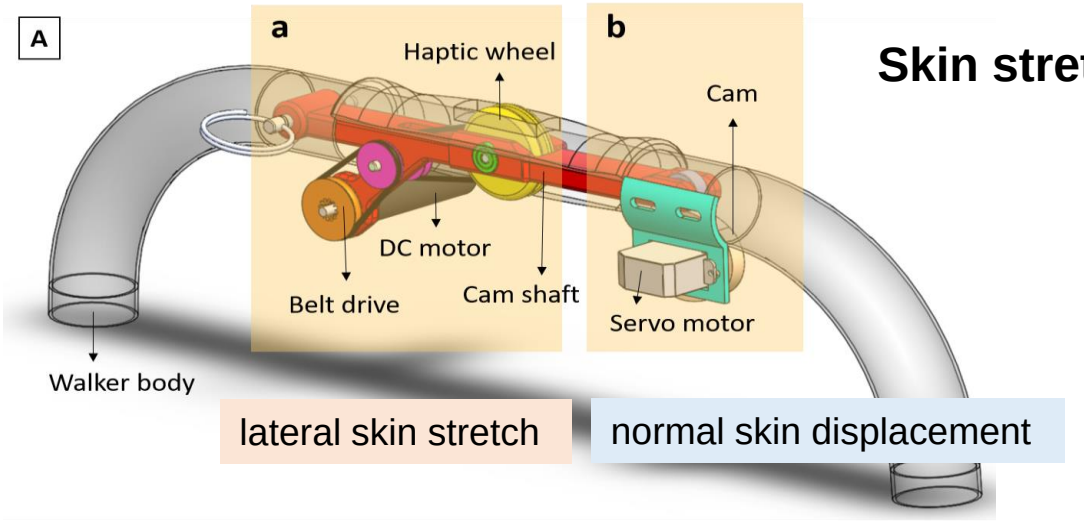


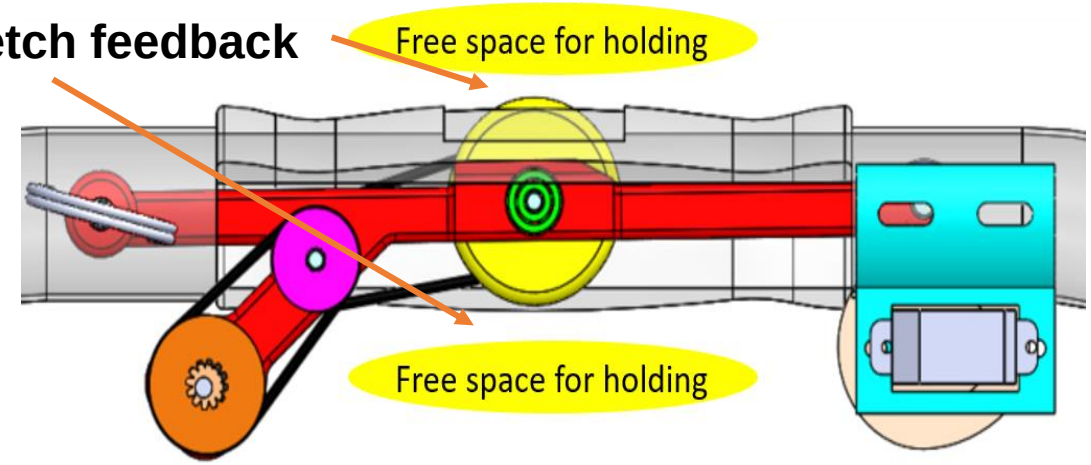
Two primary skin contact areas:
- Fingertip of middle finger
- Center of palm

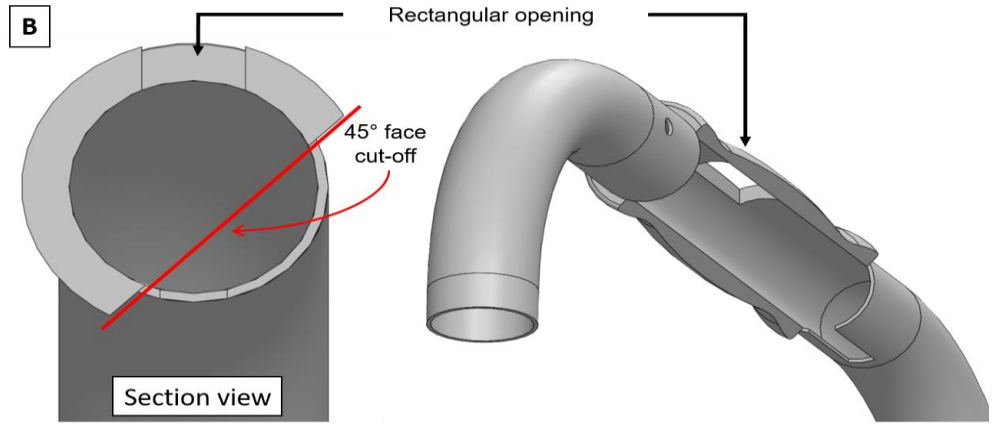


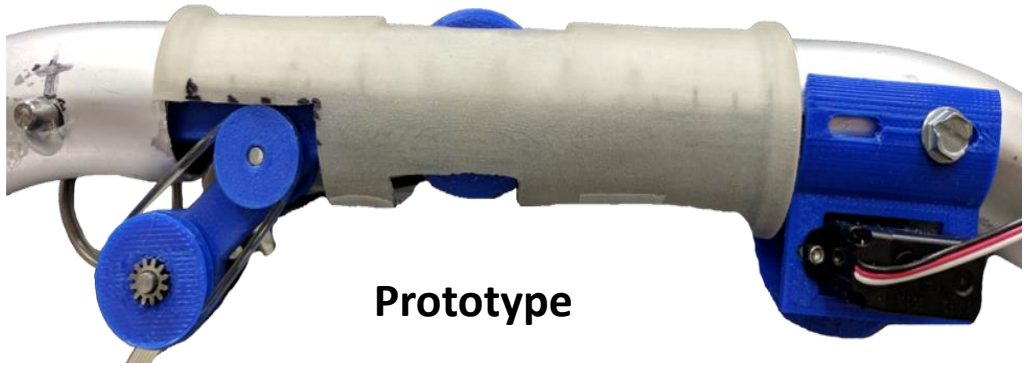
To provide one degree-of-freedom directional cues via skin stretch feedback

Design and implementation of our skin stretch device



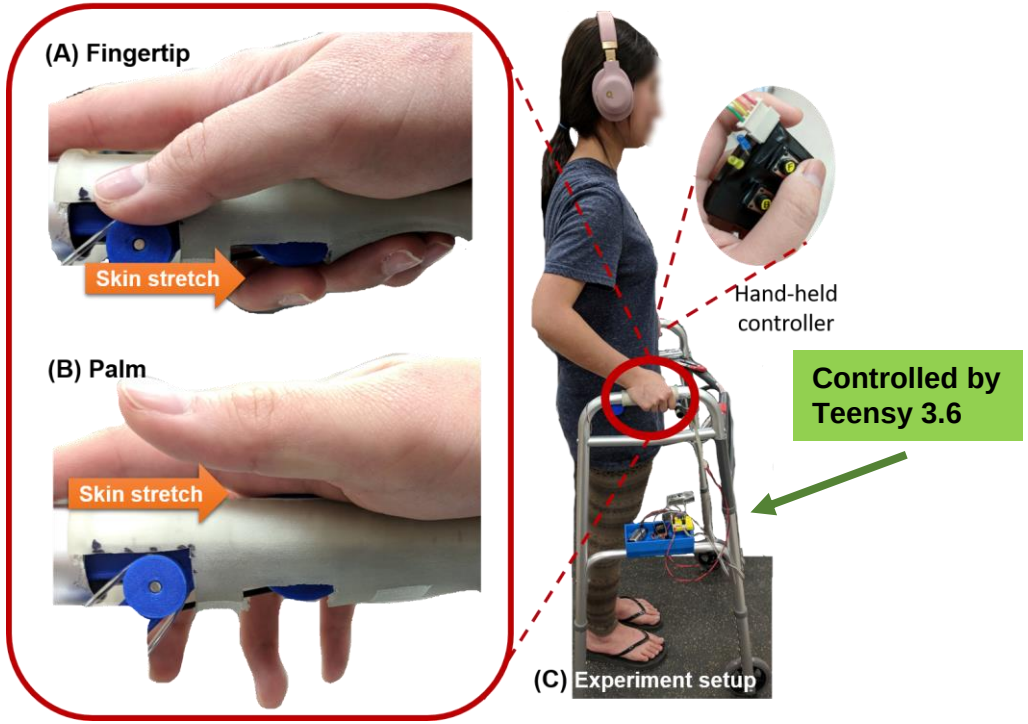






User perception study

- Objective: to evaluate the functionality of the skin stretch feedback handle on rendering directional cues (forward and backward) at fingertip and palm



Output cues

Four speeds (mm/s):
(i) 55
(ii) 85
(iii) 130
(iv) 205

Three durations (s):
(i) 0.1
(ii) 0.25
(iii) 0.5

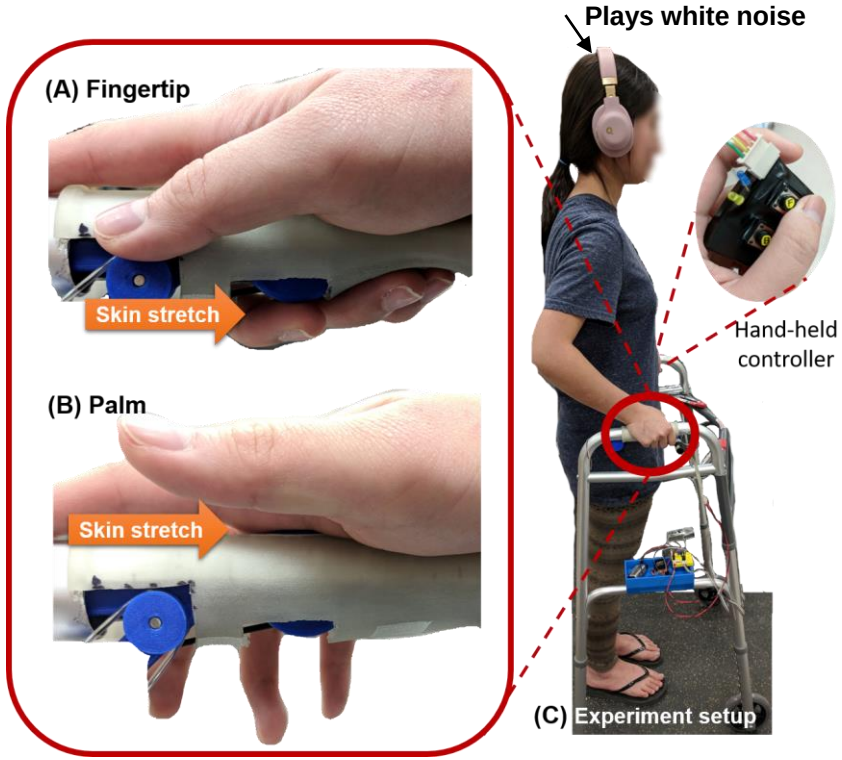
Each condition was repeated 5 times, total 120 cues, whole experiment took about one hour

Post-experiment Questionnaire

- Level of comfort
- Level of Intuitiveness
- Preferred speed and duration
- Palm
- Fingertip

Experimental Protocol

Practice → **Perceptual study at Palm (B)** → **Perceptual study at Fingertip (A)**



Given instruction:

- Palm: touch lightly on the haptic wheel (tactor) with the palm while avoiding the fingertip contact at the opposite site
- Fingertip: touch the tactor lightly with one fingertip (e.g., middle finger) while avoiding skin contact between palm and the tactor
- Do not look down at the device and focus on the cue sensation at your hand
- Press “F” or “B” button if you perceive the “forward” or “backward” direction

Quantitative Results

- From eight healthy young subjects

Palm				
Speed (mm/s)	205	66	76	75
	130	66	68	75
	85	74	65	78
	55	66	80	77
		0.1	0.25	0.5
		Duration (s)		

Finger				
Speed (mm/s)	205	93	98	98
	130	91	95	93
	85	96	94	99
	55	94	99	95
		0.1	0.25	0.5
		Duration (s)		

Mean percentage of perceiving the correct direction under twelve speed-duration combinations

- Ranges from 65% - 80%
- ≥ 75% : 6 conditions

- Ranges from 91 – 99 %
- No significant deviation from 100% : 4 conditions

Significant differences are found between perceiving the correct direction at palm and fingertip ($p < 0.05$, Student's *t* test)

Qualitative Results

Level of comfort

(1 = very uncomfortable, 7 = very comfortable)

Palm	5.3
Fingertip	5.3

Level of Intuitiveness

(1 = very difficult to understand, 7 = very easy to understand)

5.3

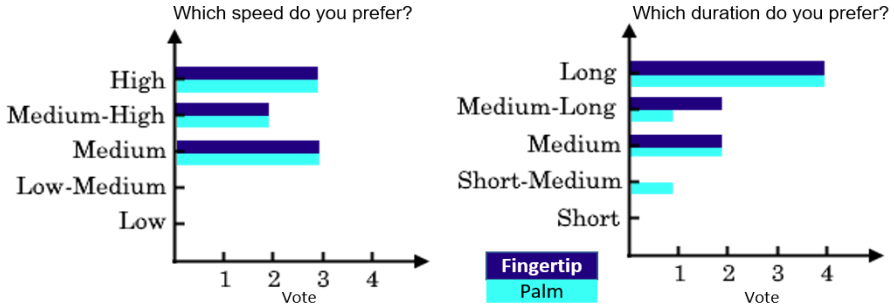
5

Two types of interpretation were observed -

(i) Skin stretch direction

(ii) Rotation direction of the wheel

Preferred speed and duration



The fingertip is favored as six out of the eight participants chose this location

All subjects were able to identify a set of three different duration whereas the *varying speeds were not as distinguishable as durations*

Conclusion and Future work

- Initial proof-of-concept prototype that can provide skin stretch feedback while holding the handgrip of a walker was designed
- Perceptual studies about how well users can discern the directions at two skin sites are assessed and compared
  - The fingertip is an ideal location for perceiving the 1-DOF directional cues (forward and backward)
  - A long and strong stimulus is preferred by the subjects

- **Future works**
  - A new device will be developed based on the preliminary evaluation of the current prototype
  - A full closed-loop system that detects user's posture and provides feedback on balance with the skin stretch feedback will be implemented

References

[1] F. Shi, Q. Cao, C. Leng, H. Tan, Based on force sensing-controlled human–machine interaction system for walking assistant robot, in: *Proceedings of the 8th World Congress on Intelligent Control and Automation*, Jinan, China, 2010, pp. 6528–6533.

[2] H. Hashimoto, A. Sasaki, Y. Ohyama, C. Ishii, Walker with hand haptic interface for spatial recognition, in: *Proceeding of the Ninth IEEE International Workshop on Advanced Motion Control,* 2006, pp. 311–316.

[3] Martins, Maria, et al. "Real time control of the ASBGo walker through a physical human–robot interface." *Measurement* 48 (2014): 77-860

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Thank you

Any Questions?

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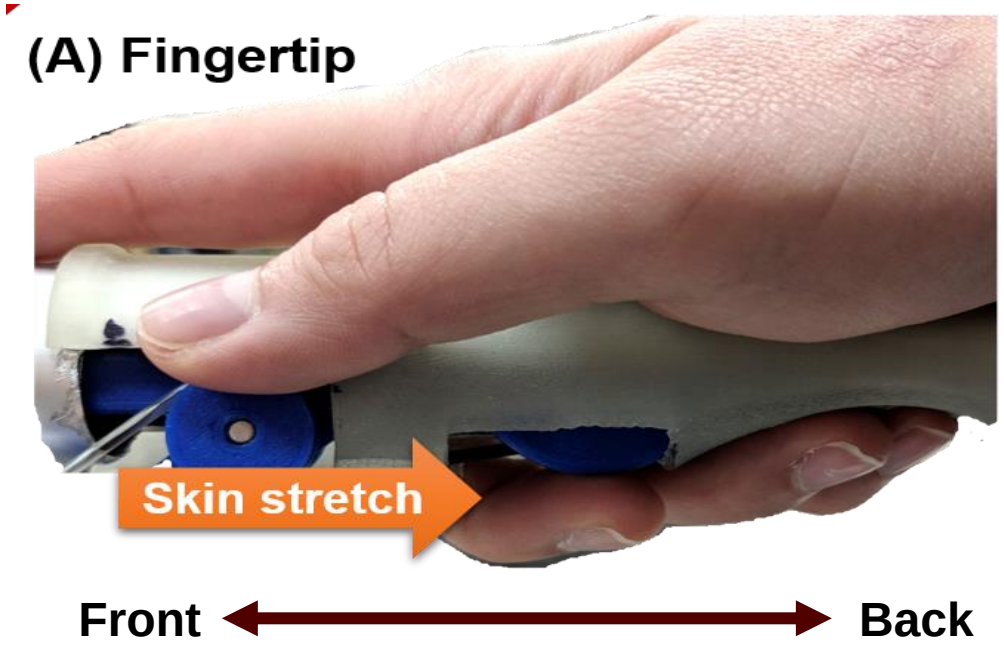
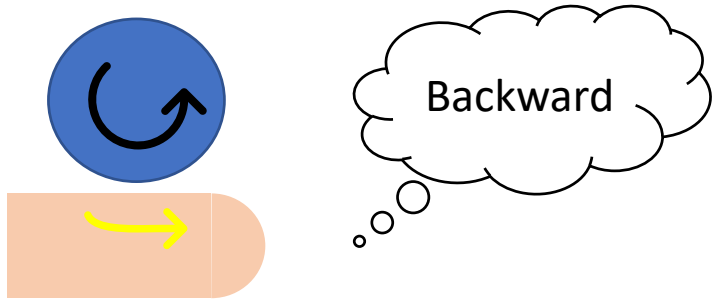
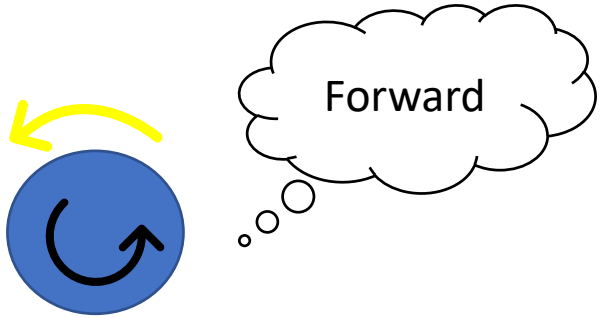
Two types of interpretation observed for the direction at the fingertip





Skin stretch direction



Rotation direction of the wheel