IDENTIFYING A PERCEPTUAL MAPPING FROM BIDIRECTIONAL SKIN STRETCH PATTERNS TO MOTOR SPACE PERCEPTIONS

MECHANICAL ENGINEERING
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INTRODUCTION

Ultimate Goal

- To develop a wearable sensory augmentation device for the elderly to alert or prevent a fall.

Motivation

- Sensory augmentation via the cutaneous skin stretch feedback has been widely used in various fields for the past decade [1]—[5].
- For human-machine interface, a control-to-display gain, e.g., the ratio between displacements of a mouse movement (mm) and a cursor movement on a screen (pixel), has an effect on user's performance.
- A perceptual mapping from cutaneous skin stretch feedback to workspace perception has not been yet taken into account.

Objectives

- To identify whether a perceptual mapping from the skin stretch pattern to the workspace perception is consistent across the subjects.

Approach

- Apply various skin stretch patterns bi-directionally by two motors.
- Build a probabilistic model with workspace variables, i.e., magnitude and direction.
- Apply the approach to an upper arm and a forearm to find more effective placement.

METHODS

Subjects

- 12 healthy young adults (9 male, 3 female, age=20-30) participated in this study.

Procedures

- Subjects were seated on a chair without hand rails, 60cm and 50cm away from a monitor and a floor, respectively, and wore an armband type skin stretch device at non-dominant hand side arm (Fig. 1).
- The subjects were instructed not to touch the chair or their body part to prevent unnecessary sensory cues except the provided skin stretch. The auditory cue was also blocked by having them to listen to music with the head phone.
- After receiving a skin stretch pattern for two seconds, the subject was instructed to point out a discrete point on the provided chart (see the chart in Fig. 1, right top) within 5 seconds.

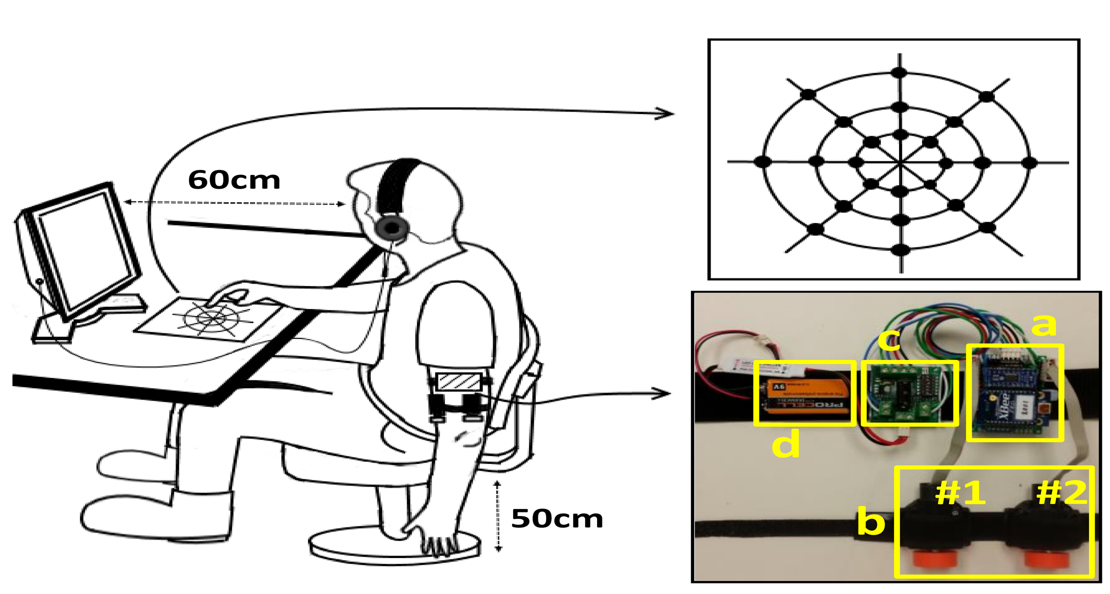

Fig. 1 Experimental setup. Subject was seated in front of a table and given instructions via a monitor (left). The subject was instructed to point out intensities and directions on the provided chart (right top). Armband type sensory augmentation device: a) 9V battery, b) motor driver, c) XBee module, and d) two motors and contactors (right bottom).

Skin Stretch Patterns, Workspace Perception, and Perceptual Mapping

- Bidirectional skin stretch patterns s_i were generated by combining the intensities of stretch by varying the speeds of two motors, i.e., H:halt, W:weak, M:medium, S:strong, and R:reverse direction (e.g., s_1=H/W).
- There were twenty-four skin stretch pattern combinations with motor#1/motor#2 : $\mathbb{S}$ = {H/W, H/M, H/S, W/W, M/M, S/S, W/H, $\cdots$, RS/H, RW/W, RM/M, RS/S}, which will be referred to as *stretch pattern set*.
- The discrete point m_i pointed out by the subjects consists of *workspace perception set* $\mathbb{M}$, which has 24 m_is according to three different intensity levels and eight directions.
- After collecting subjects' m_i followed by s_i, we computed a mapping $s_i \longrightarrow p(m|\mu_i, \Sigma_i)$ where

$$p(m|\mu_i, \Sigma_i) = \frac{1}{2\Sigma_i} e^{\frac{-(m-\mu_i)^2}{2\Sigma_i^2}}$$

by inferring μ_i and Σ_i by MLE (see Fig. 2).

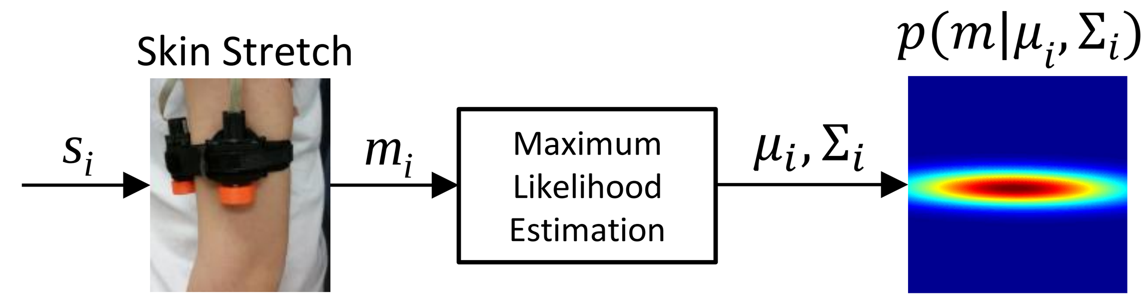

Fig. 2 Perceptual mapping $s_i \longrightarrow p(m|\mu_i, \Sigma_i)$.

Interpretation of Outcomes

- If covariance is small for a skin stretch pattern, then the pattern will be considered as a proper pattern to be used directly (Fig. 3. Left).
- Otherwise, the pattern will be considered as an improper pattern which requires remapping or warping with respect to a specific subject (Fig. 3. Right).

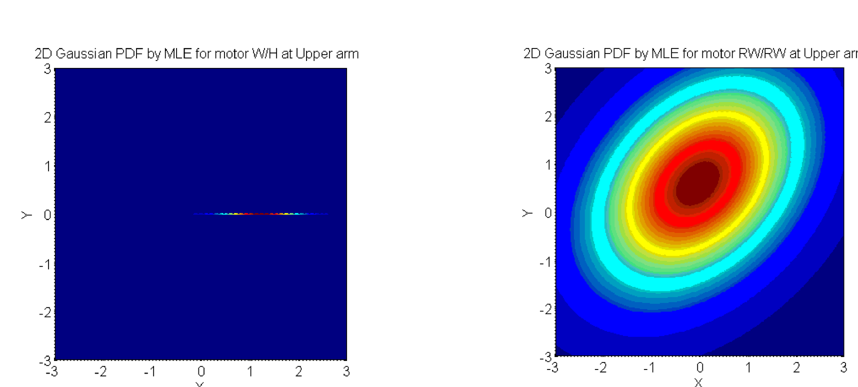

Fig. 3 (Left) Proper skin stretch pattern: $p(m|\mu_i, \Sigma_i)$ is like a thin line in $\mathbb{M}$, which means the covariance across the subjects is very small. (Right) Improper skin stretch pattern: The covariance across the subjects is very large.

RESULTS AND DISCUSSION

Estimated Perceptual Mapping across the Subjects

- Figure 4 shows $s_i \longrightarrow p(m|\mu_i, \Sigma_i)$ according to 24 stretch patterns on the provided chart.

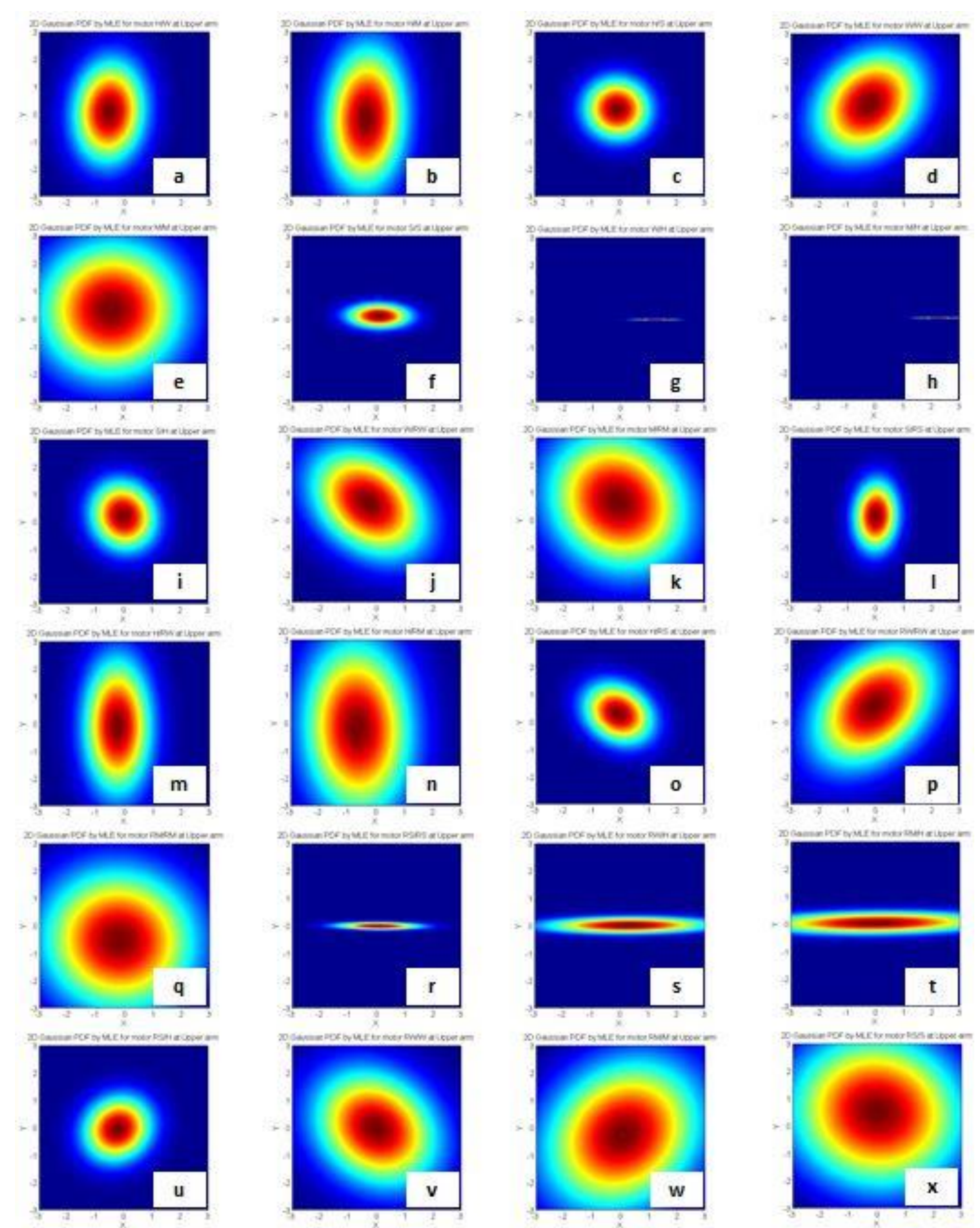

Fig. 4 : $p(m|\mu_i, \Sigma_i)$ according to twenty four $s_i \in \mathbb{S}$: (a) H/W, (b) H/M, (c) H/S, (d) W/W, (e) M/M, (f) S/S, (g) W/H, (h) M/H, (i) S/H, (j) W/RW, (k) M/RM, (l) S/RS, (m) H/RW, (n) H/RM, (o) H/RS, (p) RW/RW, (q) RM/RM, (r) RS/RS, (s) RW/H, (t) RM/H, (u) RS/H, (v) RW/W, (w) RM/M, (x) RS/S.

Skin Stretch Pattern of the Least Covariance

- Compared to other mappings, (g) W/H and (h) M/H were perceived with the distinctively least covariance for all subjects.

Stretch Patterns May Carry Directional Information

- From (g) W/H, (h) M/H and (s) RW/H, (t) RM/H, we know that directional information may be carried by skin stretch pattern when only motor#1 rotates with not strong intensity.

Simultaneous Stretch Cannot Be Decomposed

- The greater covariance was observed when two motor rotate simultaneously.

Involving Stretch Feedback at the Anterior Side and Strong Intensity May Cause Bad Perception

- From (a) H/W, (b) H/M, (c) H/S and (m) H/RW, (n) H/RM, (o) H/RS, the greater covariance was observed even when motor#1 is on halt. (i) S/H and (u) RS/H show that the covariance is greater when intensity is stronger.

References

[1] Bark K, et al., IEEE Trans on Haptics, vol. 3, no. 3, 2010
[2] Schorr S, et al., IEEE Intl. Conf. on In Robotics and Automation, pp. 2341–2346, 2013
[3] Pacchierotti C, et al., IEEE Trans on Haptics, vol. 8, no. 4, 2015.
[4] Chinello C, et al., Sirs Lab Preparing Submission, 2016.
[5] Yitsen P, et al., IEEE Trans on Neural System and Rehab Engineering, 2016.