MECHANICAL ENGINEERING
TEXAS A&M UNIVERSITY

EFFECT OF CUSTOMIZED HAPTIC GUIDANCE ON PEOPLE'S NAVIGATION CHARACTERISTICS AND PERFORMANCE

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INTRODUCTION

Motivation

- Assistive technologies for driving and navigation have been engaged for the past two decades.
- Determining the level of haptic guidance, e.g., the magnitude and direction of haptic force, is a challenging problem [1].
- For instance, an excessive guidance level may degrade user's performance and cause discomfort, whereas a lack of enough guidance may yield task-failure.

Objectives

- To provide subjects with customized haptic guidance based on their task-performing characteristics.
- To identify the effect of customized haptic guidance on subjects' task-performance and performing-characteristics.

Approach

- Subject's control strategy is parameterized by inverse optimal control (IOC), and the obtained parameters will serve as metrics to customize haptic feedback for each subject.
- The following 3 will be done: i) assigning a *coach* - an expert having the desired characteristics for the customized guidance, ii) defining a *guiding path*, and iii) determining the *level of guidance* for each subject.

METHODS

Subjects

- 16 healthy young adults (14 male, 2 female, age=20-35) participated in this study.

Procedures

- Subjects were seated at 1.5m from a 105cm-by-81cm screen, and the modified version of Novint Falcon was used as 2D haptic interface (Fig. 1).
- The experiment consisted of two separate sessions: the first session for obtaining the baseline data and the second session for identifying the effect of customized haptic feedback based on the baseline data.

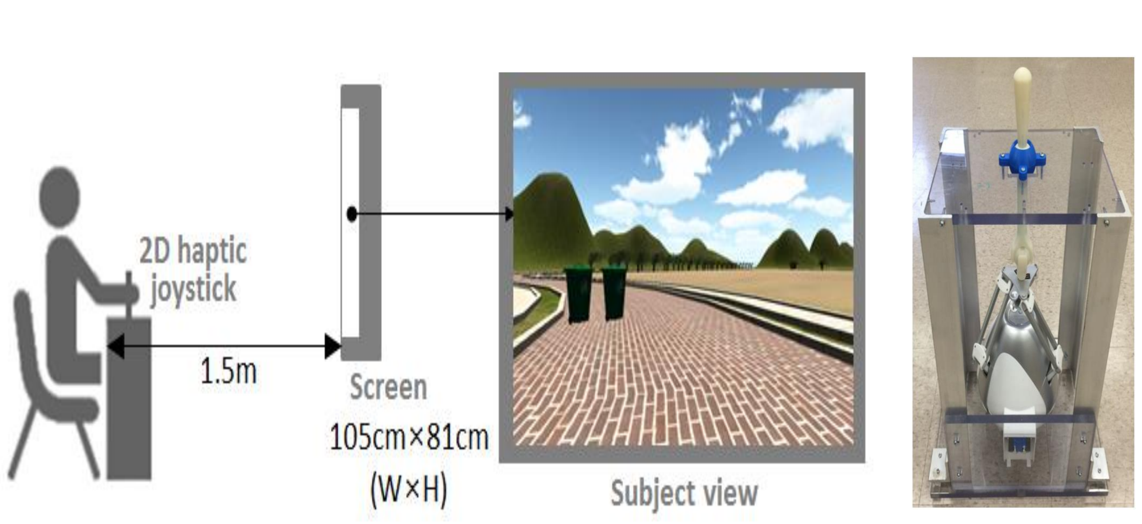

Fig. 1 The experimental environment developed by Unity3D (left) and the modified Novint Falcon as 2D haptic joystick (right).

- For both sessions, the subjects were asked to drive a virtual vehicle along four roads each of which had a difference radius of curvature and obstacles.
- The subjects were instructed to drive the vehicle as fast and safe as possible.

Data Collection

- Completion time, sampling time, task#, trial#, successes, fails, vehicle's positions and heading direction were recorded from the start line to the finish line.
- Each task was repeated 3 times. The sequence of the tasks was randomized. Sampling frequency was 60Hz.

Subjects' Strategy Parameterization

- After the first session, the subject's' strategy for given tasks was analyzed by IOC.
- A cost function that each subject may have minimized during tasks was assumed to be the following form:

$$cost = \sum_{i=0}^{N} c_v v(i)^2 + c_\omega \omega(i)^2 + c_{d_o} d_o(i)^2 + c_{d_f} d_f(i)^2$$

  where v: linear velocity, ω: angular velocity, d_o: distance from the vehicle to road boundary on obstacle side, and d_f: distance from the vehicle to road boundary on obstacle-free side.
- Positives coefficients, c_v, c_ω, c_{d_o}, and c_{d_f}, could be estimated by solving an IOC problem based on the observed baseline data v, ω, d_o, and d_f [2][3].
- (See Figure 2) Subject's vector q to represent *performing-characteristics* was defined from the estimated coefficients as $q = [c_v, c_\omega, c_{d_o}, c_{d_f}] \times 100 / (c_v + c_\omega + c_{d_o} + c_{d_f})$.

Analysis

- To examine the benefit of subject-specific customization, a baseline with no guidance and a guidance that enforced the vehicle to a road center were compared.
- Repeated measures analysis of variance (rANOVA) was performed to identify the effect of various guidance on the average and variability of subjects' performance.
- Significance level was set to 0.05 (SPSS v21, Chicago, IL).

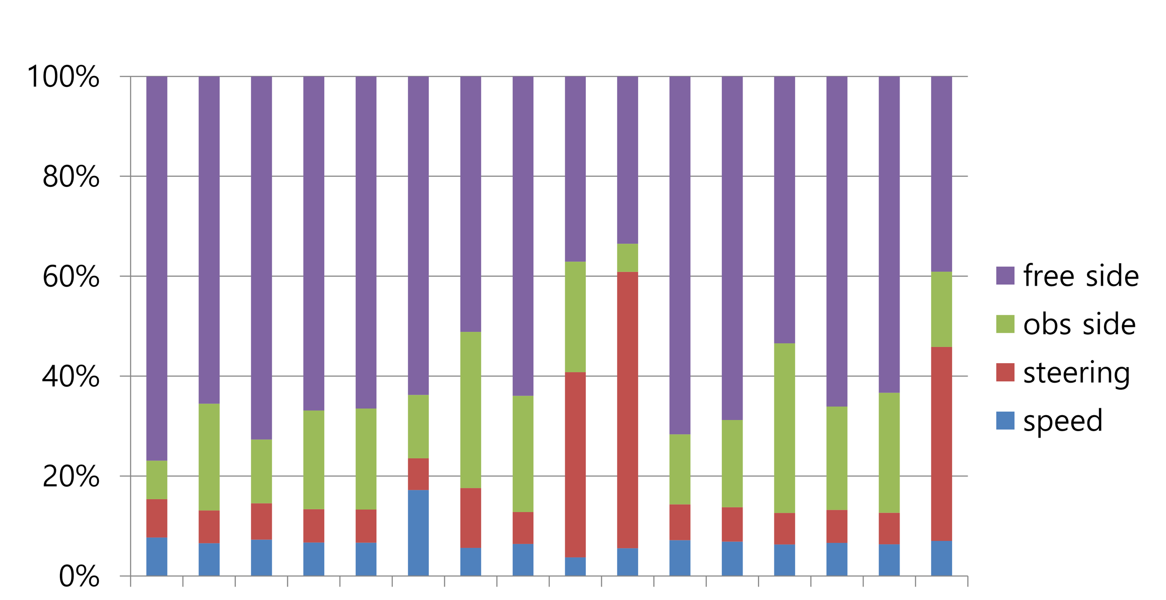

Fig. 2 Parameterized performing-characteristics vector q represented as bar graphs for all subjects

RESULTS AND DISCUSSION

Coach Assignment

- Based on the baseline data during the first session, subjects were grouped into 3 groups by k-means clustering (bold is a coach): {**s4**, s2, s5, s7, s8, s13, s14, s15}, {**s9**, s10, s16}, and {**s12**, s1, s3, s6, s11}.

Average Performance Enhanced for Slower Subjects

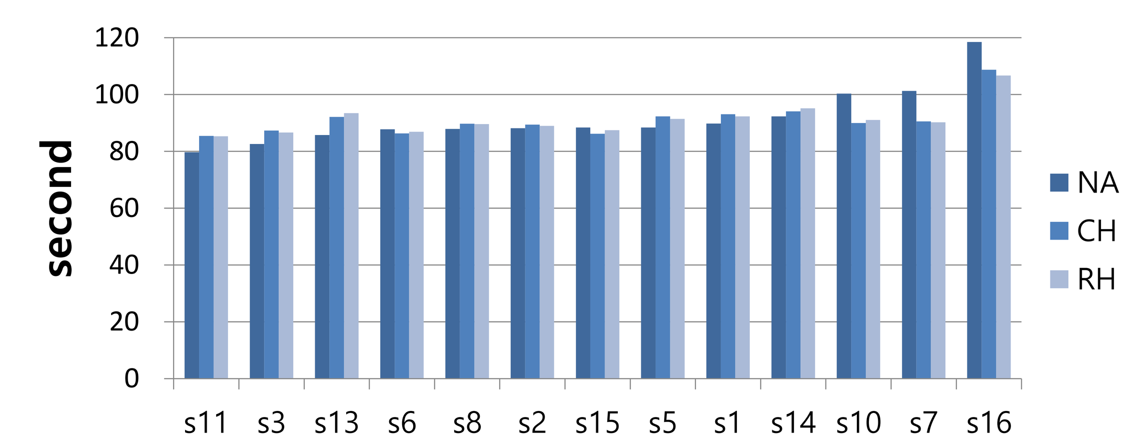

Fig. 3 Average performance with respect to NA (no-assist), CH (customized haptic), and RH. (road-centered haptic).

- The average of subjects' performance was not significantly affected by haptic assistance.
- <u>Performance improvement could only be observed in slower subjects</u>, e.g., s10, s7, and s16.

Performance Variability tended to reduce

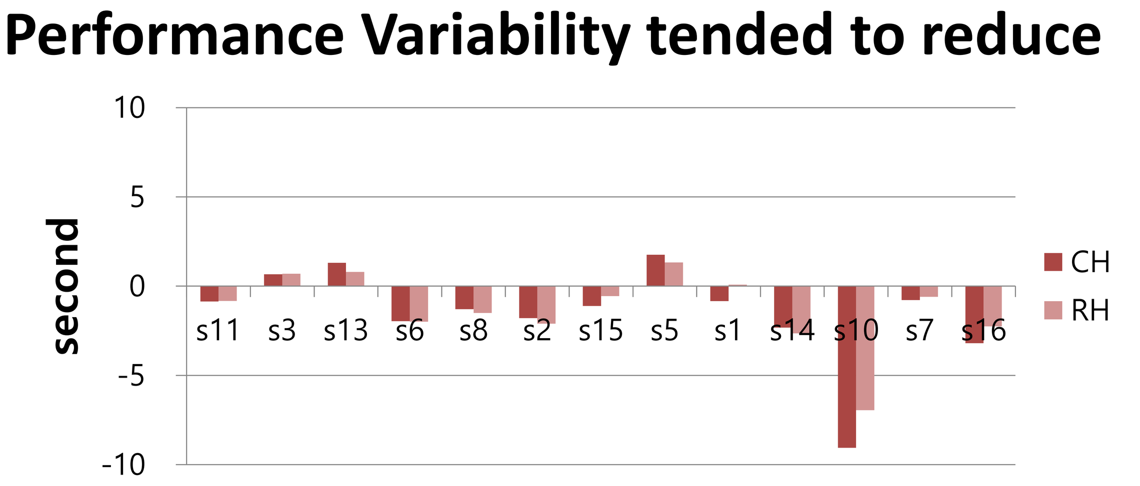

Fig. 4 The performance variability difference from NA when CH and RH was provided.

- rANOVA on performance variability showed <u>tendency for variability reduction when haptic guidance was provided</u>, $F(2,24)=4.168$, $p=0.06$, with mean of 3.929, 2.430, and 2.658 for NA, CH, and RH, respectively.

CONCLUSION

- To provide with the customized guidance, our approach for parameterizing subjects' control strategy was presented.
- The customized haptic guidance *only enhanced the slower subjects task-performance*.
- The customized haptic guidance (CH) showed *the stronger tendency for variability reduction* compared to road-centered haptic guidance (RH).

References

[1] Feygen D. et al., IEEE Symp. on HAPTICS, FL, USA, 2002
[2] Suzuki S. and Furuta K. J. control Science and Engineering, 1-10, 2012.
[3] Levine S and Koltun V, IEEE Conf. on Machine Learning, Edinburgh, Scotland, 2012.