Characterizing the Effects of Haptic Rendering Parameter Variations on Perceived Kinesthetic Rendering Accuracy

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***Abstract*— To understand how the realism of a kinesthetic haptic rendering is affected by the accurate selection of the rendering model parameters, we conducted a preliminary user study where subjects compared three real-world objects to their equivalent haptic rendering. The subjects rated the rendering realism as the model parameters were varied about their nominal values. The results suggest that the required accuracy of various haptic rendering parameters is not equally important when considering the perceived realism.**

I. Experimental Methods

We investigated the perceptual importance of kinesthetic rendering parameters [1,2] by having subjects compare three real-world objects to an equivalent haptic rendering. We selected three objects (1) a doorknob, rendered using a stiffness model with a parameter *k*, corresponding to the linear stiffness, (2) a deadbolt lock, rendered using a sinusoidal detent model with parameters *A* and *W*, corresponding to the detent amplitude and width, respectively, and (3) a faucet knob, rendered using a Dahl friction model with parameters, σ, and τ_c, corresponding to the initial stiffness and steady-state friction magnitude, respectively (see Fig. 1). The selection of these was motivated by the desire to have a variety of haptic sensations that could be rendered using a one degree of freedom rotational haptic device. To allow for interactive comparison, the test bed was designed to present users with three side-by-side distinct interfaces including (1) the physical object, (2) a nominal haptic rendering of the object (the parameters of which were collaboratively determined among five confederate people with background in haptics), and (3) a haptic rendering of the object where a single haptic rendering parameter was varied from the established nominal value. The haptic interfaces were designed to match the physical dimensions of the real-world objects. Five tests, corresponding to the five haptic rendering parameters of the three real-world objects, were carried out on ten subjects. During each test, a single haptic parameter was varied, and the subjects rated the realism of the rendering on a ten-point scale, where higher scores corresponded to better realism and the nominal rendering was assigned a value of seven. For each haptic parameter, 11 distinct parameter values, evenly spaced between the maximum and minimum parameter value and centered about the nominal value, where displayed in random order on the haptic interface. The minimum and maximum parameter values were set to 50% below and above the nominal value, respectively.

*This work was supported by NSF award 1830242.

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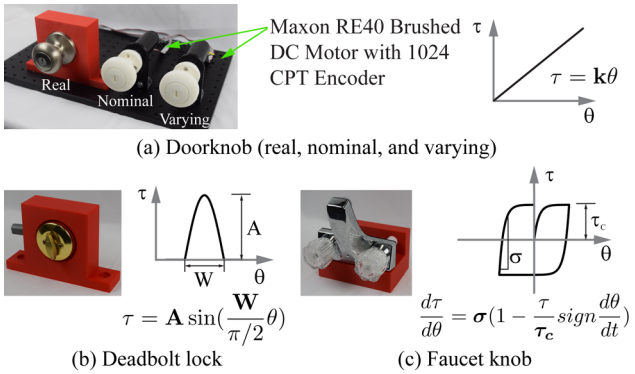

(a) Doorknob (real, nominal, and varying)

(b) Deadbolt lock (c) Faucet knob

Fig. 1. Overview of experimental setup and rendering models.

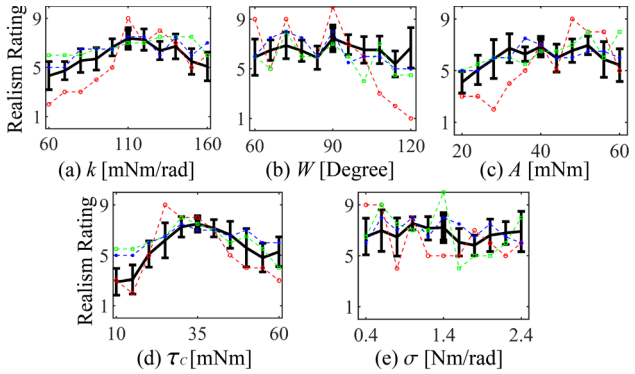

Fig. 2. Results: (a) stiffness, *k*, (b) detent width, *W*, (c) detent amplitude, *A*, (d) and (e) Dahl friction steady-state friction, τ_c, and stiffness, σ, respectively. Black: average realism ratings of all subjects with error bars showing 95% CI. Red, blue, and red: typical individual data from three subjects.

II. Results and Discussion

The experimental results are shown in Fig. 2. We see that the variation of the Dahl steady-state friction magnitude and the linear stiffness shows a distinct region, centered about their nominal values, where the perceived realism is highest. In contrast, the variation of the Dahl stiffness and detent width show little if any perceived change in realism. The results suggest that the required accuracy of various haptic rendering parameters is not equally important when considering the perceived realism of a given haptic interface. Future work will focus on examining a wider range of objects and haptic rendering effects.

References

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