Haptic Props: Semi-actuated tangible props for haptic interaction on the surface

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ABSTRACT
While multiple methods to extend the expressiveness of tangible interaction have been proposed, e. g., self-motion, stacking and transparency, providing haptic feedback to the tangible prop itself has rarely been considered. In this poster we present a *semi-actuated*, nano-powered, tangible prop, which is able to provide programmable friction for interaction with a tabletop setup. We have conducted a preliminary user study evaluating the users' acceptance for the device and their ability to detect changes in the programmed level of friction and received some promising results.

Author Keywords
Tangible interaction; tabletop; nano-powered devices

ACM Classification Keywords
H.5.m. Information Interfaces and Presentation: Miscellaneous

General Terms
Experimentation, Human Factors

INTRODUCTION
Tangible interaction on a tabletop computer has received reasonable attention in miscellaneous application domains, ranging from music synthesizer to geo-spatial application or medical visualizations. Alongside the interaction techniques diverse physical props (so called *tangibles*) with different forms, sizes or capabilities have been proposed. *Active tangibles*, which are able to change their position and orientation and provide haptic feedback, seem to be rather promising. However, the improved properties of these devices come at a cost. Currently, there are two main approaches to build an active tangible: (1) by adding a grid of (magnetic) actuators under the tabletop [3], which is then used to activate the prop, e. g., moving it along the surface, or (2) by adding electronics, actuators (e. g., motors) and power units into the prop itself. While the first method facilitates the usage of simple, mechanical tangibles, which are usually small, cheap and easy to produce or prototype, the tabletop setup itself becomes complex and expensive. Furthermore, due to mechanical constraints such setups usually provide relatively coarse-grained control and higher latency and are inherently difficult to scale up above a certain size or down to the size of a mobile device.

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Figure 1. An image of a disassembled Haptic Prop. Notice the single CR2032 battery, which can power the device for up to 5000h.

On the other hand, the actuators built into the props are usually power intensive units, which allow only limited continuous usage periods (about 3-4 hours according to [2]). Such limited usage periods combined with the relatively long recharging times hinder the usability of this type of props and make interfaces, which require many tangibles to be used simultaneously or to be readily available, unfeasible. In addition, the size and the number of the required power cells often imposes a hard lower boundary upon the size of the props which may be well beyond the requirements of the interface itself.

In this poster we present the *Haptic Prop* - a tangible (shown in Figure 1) which provides programmable friction response when moved or rotated by feeding part of the operational effort back to the user. This approach drastically reduces the amount of required external power and thus the device's size, cost and most importantly maintenance effort, filling this way the gap between the simple passive props and the fully-powered active tangible bots.

HAPTIC PROP
Basically, our Haptic Prop device extends the ingenious initial approach by Badshah et al. [1] to the TUI on the tabletop. Therefore we use 4 DC motors (cf. Figure 1) with metal gearing and gear ratio $1:50$, which are designed for $30-400$ rev-

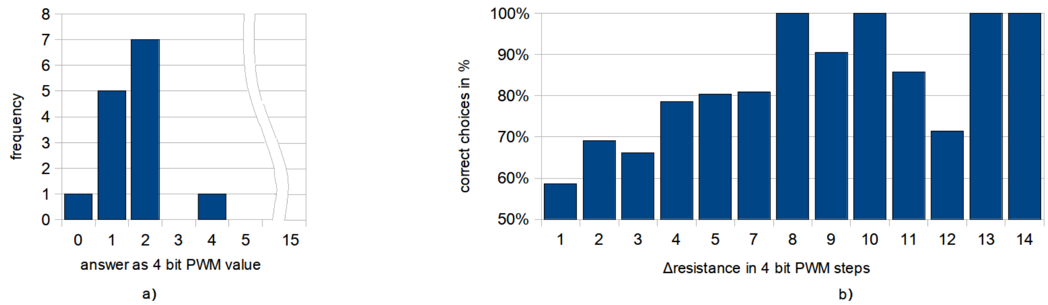

Figure 2. Results of the conducted preliminary user evaluation: a) minimum sensitivity task and b) the discrimination task.

olutions per minute (rpm). As in the InGen the motor pins are short-cut through an electronic switch, which is controlled by a microcontroller unit. Thus if a motor's rotor is rotated, the motor will produce electrical power, which will then be fed back to it (if the electronic switch is closed) and try to rotate the rotor in the *opposite* direction, i. e., the motor will "resist" to the applied force. Through fast switching the short-cut driver on and off one can control the level of this resistance force, which is perceived as continuous by the user. The switching of this short-cut driver is controlled by a microcontroller unit, which receives commands from the tabletop computer through an infrared channel. Commands are sent on every rendered frame, which provides fast dynamic control of the feedback level, while allowing the controller to "sleep" most of the time. Finally, the motors are attached to omni-directional wheels, which allows the user to move and rotate the device into arbitrary directions without re-orientating it.

In contrast to the InGen, we have decided to power the control circuit from a separate power cell, which allows for instantaneous response to the user actions. Zero-powered devices do not need any external energy sources, but may introduce latency of up to $250ms$ [1] due to the fact that they have to wait some time until enough power has been harvested. On the other hand, our approach allows instantaneous response of the device, but adds some small maintenance cost. The current research prototype, for instance, allows up to 5000 hours of continuous work, powered by a single CR2032 lithium cell, which would require changing the battery every 6 months. However, due to recent advances in the low-power electronics domain (e. g., Microchip's XLP Technology) we believe that it is possible to reduce the power consumption so much that the discharge time of a single battery outlasts the typical device lifetime.

PRELIMINARY USER EVALUATION

In a preliminary evaluation with 7 students of our department (age 21 – 37, 6 male and 1 female) we have analyzed the users' sensitivity to the haptic feedback provided with our device. The total time of the experiment took approximately 30 minutes per subject. After completing a short questionnaire the subjects had to judge the minimum detectable friction level. Therefore we have consecutively increased the applied braking force on a 16 point scale from 0 - no braking to 15 - full braking force, while the subject was pushing the device along a predefined linear path. The subject had to press a button at the moment when she first felt the applied friction. A histogram of the results of this task is shown in Figure 2 (a). As one can see from the histogram, subjects were pretty sensitive to the applied feedback.

In the second part of the experiment, we have evaluated the users' ability to discriminate between two different friction levels. For this task the subjects had to move the Tangible over two outlined areas, that were placed side by side, and they had to indicate which area presented higher resistance intensity by pressing a keyboard key. For this test we applied 32 different pairs of feedback, which were randomly chosen and uniformly distributed. Each pair was presented exactly twice. The results, shown in Figure 2 (b), indicate that the user could reliably detect level spacings larger than 3. While this is a relative high margin, we expect that the actual detection threshold is far smaller, and these results are merely reflecting the small number of participants and trials. Indeed, as one could see in Figure 2 (b), the users' responses for spacing of 2 were correct in more than 70% of the cases.

CONCLUSION AND FUTURE WORK

In this poster we have presented the *Haptic Props* - a semi-actuated tangible for interaction on a tabletop, which is able to provide dynamically controllable friction response to the user. Although in very early development stage, the device has already found positive acceptance by users. In future research we want to improve the hardware by reducing the size and the complexity of the mechanics and utilizing current state of the art low-power electronics. Furthermore, the ability to independently control the friction response in different directions opens a wide range of new interface design opportunities, which seem worth to be explored in the future.

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