Active Haptic Feedback for Touch Enabled TV Remote

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ABSTRACT

Recently a number of TV manufacturers introduced TV remotes with a touchpad which is used for indirect control of TV UI. Users can navigate the UI by moving a finger across the touch pad. However, due to the latency in visual feedback, there is a disconnection between the finger movement on the touchpad and the visual perception in the TV UI, which often causes overshooting. In this paper, we investigate how haptic feedback affects the user experience of the touchpad-based TV remote. We described two haptic prototypes built on the smartphone and Samsung 2013 TV remote respectively. We conducted two user studies with two prototypes to evaluate how the user preference and the user performance been affected. The results show that there is overwhelming support of haptic feedback in terms of subjective user preference, though we didn't find significant difference in performance between with and without haptic feedback conditions.

Categories and Subject Descriptors

H.5.2 [**User Interfaces**]: Haptic I/O

General Terms

Interaction, Feedback

Keywords

Haptic; Touch; User Study; TV Remote

1. INTRODUCTION

Grid-based UI is widely adopted in existing Smart TV products, such as Samsung Smart TV, Google TV, Roku etc. A highlight is used to indicate where the currently focused UI element is. For example, Figure 2 shows a grid-based TV with the highlight at the top right corner. The users navigate the UI by moving the highlight with arrow keys on TV remote.

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Figure 1: 2013 Samsung Smart Touch Remote.

To keep users attention on the screen, decrease the energy consumption and keep the cost low, TV remote generally don't have a screen. Therefore, interaction with TV UI via the remote is indirect and relies on various types of feedback, such as visual, auditory and tactile.

Recently a number of TV and set top box (STB) manufacturers introduced touchpad based TV remotes. Notable examples are the Samsung 2012-2013, Sony 2014-2015, Sharp 2015 and Dish 2015. With such remotes, sliding a finger across the surface of touchpad moves a highlight by one or several steps in grid-based UI. Indirect interaction with a TV screen via handheld touch surface causes a sensory disconnect leading to navigational errors. The most typical such error is overshooting, meaning that the finger moved too far and the highlight switched to the item passed the desired one. We theorize that the main cause of this is a significant feedback delay, meaning that by the time visual information is processed by brain, finger may have already moved too far.

In this paper we investigate the effects of adding active haptic feedback to touchpad based remote. In particular, we are interested in whether this additional haptic feedback can bridge the disconnection and improve the user experience of touchpad-based TV remote. In the following sections we describe our design considerations of haptic feedback, two haptic TV prototypes based on smartphone and Samsung 2013 touchpad based TV remote, and two user studies with 17 participants total evaluating the users' preference and performance with our haptic prototypes.

2. RELATED WORK

It was shown previously that active haptic feedback can

- enhance user experience, providing enjoyment and increased feel of engagement. Levesque et al [6] explored the design possibilities and outcomes using a large area textile pattern display. They found that variable friction demonstrated a positive impact on the enjoyment, engagement and sense of realism of touch interfaces.

- increase the sense of realism by restoring mechanical feel. Some researchers investigated new technologies to render mechanical haptic feedback in a higher level of realism. For example, Bau et al [1] presented a electrovibration–enabled touch surface, which provides a wide range of tactile feedback sensations to fingers moving across. Their experiments are promising for designing realistic and effective tactile feedback.

- measurably increase the performance for targeting tasks. Burke et al [2] conducted a meta-analysis comparing visual-auditory and visual-tactile feedback on user performance. In general, additional modality added to visual feedback improves performance overall. But visual-tactile feedback is more effective when multiple tasks are being performed and workload conditions are high. Richter et al [10] reported similar results obtained in multitasking situations such as the interaction with touch-based in-vehicle systems. Their preliminary quantitative study shows significantly reduced error rates as well as input time in with-haptic feedback condition.

- decrease the reliance on vision. Pasquero and Hayward [8] evaluated the use of tactile feedback in navigating a long list in mobile UI. They used a hand-held device which tightly coupled the touch input and haptic feedback. Their results showed 28% decrease of reliance on vision when tactile feedback was enabled.

Inspired by these previous research, we investigate whether additional haptic feedback on TV remote can have similar effects to improve user experience of TV UI.

3. DESIGN OF HAPTICS

Providing haptic feedback to TV UI is not a trivial task. Three types of design decisions should be made. First of all, we need to identify what type of hardware solutions is appropriate to augment TV remote with haptic modality. Secondly, we need to identify the TV interaction scenarios which is appropriate to use haptic feedbacks. Thirdly, we need to understand how haptic modality work with other modalities, such as visual and auditory.

Haptic Hardware. For the first design question, we considered several types of haptic actuators. Some haptic actuators change the physical shape of interaction surface [11]; some induce haptic sensation by electrostatic vibration [1]. The most widely used and commercially available haptic actuators are based on mechanical vibration of the interaction surface, such as Eccentric Rotating Mass (ERM), Linear Resonant Actuator(LRA), Piezo and Electro-Active Polymer Actuators (EAPs).

We ruled out shape changing actuators as interfering with smooth finger movement over touch surface. We also ruled out electrostatic vibration actuators as requiring high voltage, which is problematic in form factor of handheld remote control. ERM needs a time to spin out motors and therefore have higher latency. For our prototype LRA was chosen as having both low latency and low power consumption. To provide feedback in situations of finger being off touchpad surface we attached haptic device to the back surface of the remote, so it was being felt by a palm.

Haptic Interaction Design. For the second design question, we focus on providing haptic feedback for the most basic TV UI interaction, which is moving highlights up, down, left or right. Because of this simple navigation task, the haptic effect design is also relatively simple. We decided to provide a sharp click haptic effect to a highlight move event. Every time when the user's finger movement on the touch pad triggers the highlight to move one step on the TV UI, a haptic sharp click is also triggered.

Congruency with Other Modalities. For the third design question, we need to understand how haptic modality should be coordinated with other modalities, such as visual and auditory. In other words, would it matter if haptic modality work independently or should it be time-synced with other modalities? According to Lylykangas et. al. [7], a preferred perception of tactile feedback requires careful design and controlling of the timing parameters. Haptic feedback is more sensitive to latency than a visual feedback. Jay, Glencross and Hubbold [5] found that "whilst latency affects visual feedback from 50 msec, it impacts on haptic task performance 25 ms earlier, and causes haptic measures of performance deterioration to rise far more steeply than visual." As cited in [3], in terms of discerning consecutive events tactile sensation is in between visual and sound stimuli, being 5 ms vs 25 ms and 0.1 ms respectively. Based on that number, Poupyrev et al [9] suggested that "minimum required latency of a tactile actuator to be 5 ms". As we mentioned earlier about overshooting issue, indirect interaction with a TV UI via touch on a remote leads to a sensory disconnection. On the one hand, our hypothesis is that overshooting is a result of a feedback latency, thus we should reduce the latency of haptic feedback as much as possible. On the other hand, haptic and visual feedback should act in a time-synced manner. To understand how the latency affect haptic feedback, we decided on two different latency values: 5 ms and 25 ms with latter aiming at keeping haptic and visual feedback in a time-synced manner.

The latency value has a big impact on implementation of TV system. Thus, 5 ms latency would require all processing to happen on the remote itself to avoid communication round-trip delay between the remote and TV, while 25 ms and longer latency could be achieved having much simpler implementation of software on TV host.

4. FIRST PROTOTYPE AND PILOT STUDY

For rapid prototyping we developed a prototype emulating touchpad behavior using smartphones. Specifically, we used QT based Nokia N9 and Android based Samsung Galaxy S3. Both phones have embedded LRA haptic actuators.

A quick pilot study was conducted to assess 8 participants' preference for haptic feedback. In the study, an app on a Nokia N9 smartphone was developed to simulate a remote control directional pad (d-pad).

In the Samsung 2013 SmartHub a user navigates the TV User Interface by flicking and sliding her finger across the

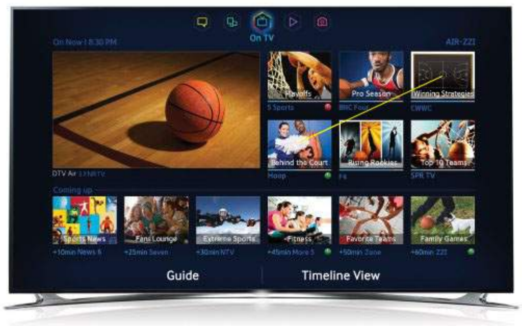

Figure 2: SmartHub, with yellow line indicating highlight move.

touchpad surface. Depending on tracking speed settings each finger movement may result in one or more directional navigation commands. For example, sliding to the right and a bit up may cause a Right-Right-Up sequence to be sent to the TV. This behavior corresponds to pressing the directional buttons on a traditional button based remote causing the highlight to move in the grid based UI, see figure 2.

Participants used the smartphone as a touch pad to navigate through lists of movie and TV show posters on TV and type on an on-screen keyboard. In a counterbalanced order, participants navigated with and without haptic feedback. Afterwards they stated their preference for haptic or no-haptic feedback.

All 8 participants preferred haptic feedback. Here are some quotes from N9 study explaining why participants did prefer haptic.

P1 "I prefer the buzzing, it feels like it makes me make meaningful decisions."

P2 "it almost gives me another sense of knowing I am going in the right direction."

P3 "subconscious thing, reassuring that I am doing a right thing."

P4 "I like the vibration a lot. It lets you know you did something... it lets you know you made one jump or two jumps or something..."

Encouraged by the results of the pilot study, we proceed to evaluate how haptic feedback affects the user performance as well as user preference when navigating the grid-based TV UI.

5. SYSTEM IMPLEMENTATION

To achieve a high fidelity prototype, we used the 2013 Samsung Touch Remote Control as a primary hardware platform, see figure 1. Haptic hardware consisted from LRA actuator and a controller from Texas Instruments implementing Immersion [4] library of haptic effects. Actuator was placed on the bottom back of the device. "Sharp Click" effect of immersion library was tuned to get a crisp rendering effect.

The TV platform was implemented as PC application communicating with remote prototype via Bluetooth connection at 60 Hz. There was no explicit audio feedback and haptic actuators were silent as well.

Haptic activation commands were issued immediately after directional navigation command. Navigation software that converts finger movement on touchpad to navigational commands was implemented in two variants: as a JavaScript code running on the PC — variant B; and as a native code running on TV remote embedded processor — variant A.

Variant B besides being a less complex implementation provided a tighter synchronization between haptic and visual feedback since navigation and UI updating were done on the same machine. However, it relied on Bluetooth channel to convey haptic commands and hence introduced additional communication latency as long as 15 ms.

Variant A was implemented in C++ for ARM processor in TV remote. Thus, on the remote control, end-to-end haptic latency was estimated to be as low as 5 ms vs 25 ms for variant B.

6. USER STUDY

6.1 User Study Design

Each participant was asked to complete 12 practice trials and 108 test trials composed of the factorial combination of 3 tracking speeds (fast, medium, slow) - see section 4, 3 haptic conditions (A: 5ms, B: 25ms, No Haptic) - see section 5 and 12 trial types. The trial types were composed of 3 target sizes (large, medium, small) and 3 movement directions (horizontal only, vertical only, diagonal); plus for small targets only there were both long and short movements. None of the tasks involved scrolling. There were 9 blocks of 12 test trials for each participant. The order of the blocks was counterbalanced using a 9x9 Latin Square.

These factors were designed to represent the domain of TV navigation tasks and to allow a detailed analysis of which tasks might be more affected by the haptic feedback.

The trials were designed to simulate the common tasks of navigating to a known target position on the TV screen. Real life examples included selecting an item from a menu, selecting a TV show in a program guide, and selecting a key on an on-screen keyboard.

Although performance improve over time is an interesting topic, our experiment was not designed to collect enough data to answer such question.

6.1.1 Participants

Nine participants were recruited for this one-hour study. Participants included 5 females (ages: 22, 27, 34, 44 and 55) and 4 males (ages: 27, 31, 38 and 57). Participants sat on a sofa holding the touchpad remote control (figure 1) about 10 feet from a 55 inches Samsung LED TV.

6.1.2 Data Collection

To initiate each trial, the participant clicked the touchpad remote, which presented a grid of cells on the TV screen (see figure 3). One of the cells, the target, had a unique color. The task was to use the touchpad to move the highlight (which always started on the top left cell) to the target cell as quickly and accurately as possible. After selecting the target by highlighting it and clicking the touchpad, the participant could initiate the next trial. Task time, number of cells navigated and accuracy were measured for each trial.

For each block of 9 trials, representing a tracking speed and haptic condition, the participant rated the usability of

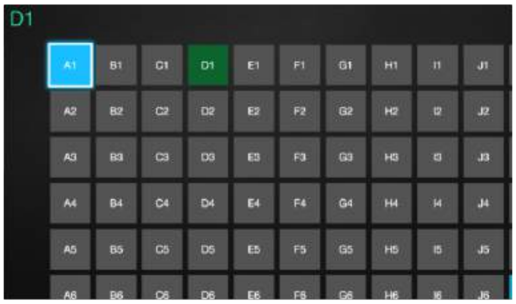

Figure 3: Sample task: Participants used the touchpad remote to move the highlight (blue) to the target cell (green) as quickly and accurately as possible.

the touchpad on a Likert scale ranging from 1 (very unusable) to 7 (very usable).

6.2 Results

The task time, errors, number of cells navigated and user ratings were analyzed with ANOVA for tracking speed and haptic conditions. None of the effects of time, errors or ratings were significant. There was a significant effect of tracking speed on number of cells navigated $F(2, 16) = 10.79$; $p < 0.001$. The faster the tracking speed, the more cells were navigated (8.2 cells, 8.6 cells, 9.8 cells, respectively). This is consistent with correlation of people overshooting the target and correcting with greater tracking speeds. After participants completed all the trials they were asked to choose which haptic condition they preferred (A: 5ms, B: 25ms, No Haptic) Although, some participants had difficulty distinguishing between the A: 5ms and B: 25ms conditions, 8 of the 9 participants preferred haptic feedback over no haptic feedback. *Binomial Probability* $p = 0.039$.

6.3 Discussion

Although the experiment did not find a performance effect, participants had a clear preference for haptic feedback. We are especially confident in this conclusion when combined with the results from our earlier study using a Nokia N9 phone to simulate a remote control in which all 8 participants preferred haptic feedback. Our current study doesn't provide the reason behind the overwhelming preference, but plausible explanation could be feeling of responsiveness. We plan to explore this in future work.

The current experiment was powerful enough to detect the effect of tracking speed on user performance, however, an effect of haptic feedback on performance was not found. This would be expected if the haptic effect on performance is relatively small. Future experiments could include more participants and/or trials to increase the power of the statistical tests to measure effects of haptic feedback on performance.

In absence of such measurable effect on performance we think that haptic UX design should focus user *subjective* satisfaction. It means, rather than striving to get the earliest possible feedback emphasize haptic as another feedback modality, make it synchronized with visual stimuli. Future studies are necessary to validate our hypothesis.

7. CONCLUSION

In this work we investigated benefits of adding active feedback to touchpad based TV remote control. Two prototypes were built with approximately 5 and 25 ms latencies. In the conducted user study 8 out 9 participants prefer haptic enabled remote, though we didn't find significant performance difference. Although, performance findings do not confirm prior art conclusion about haptic performance benefits and need to be verified in future work. Despite that, we conclude that adding active haptic feedback significantly improves self reported satisfaction and leads to improved user experience.

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