Hapick: New Foot-Based Device with Haptic Feedback for Hotkey Input as Angular Menu System

Yeon Su Park
KAIST SoC
yeonsupark@kaist.ac.kr

Suhyeon Park
KAIST SoC
0111suhyeon@kaist.ac.kr

Seonghyun Yang
KAIST SoC
jysh1023@kaist.ac.kr

ABSTRACT

With an increase of digitalization, many jobs require computer usage for a prolonged period of time. This builds up fatigue on wrists and hands, and the development of hotkeys became a lifesaver. This significantly decreases the amount of typing and helped the users to work efficiently. However, hotkey presses require both hands on the keyboard, and difficult key combination requires users' focus and context switching from monitor to keyboard. It also restricts users' sitting position, causing fatigue along arm and shoulder. In this paper, we present Hapick – a feet-worn device which allows easier, comfortable, yet effective input of hotkeys. This device adapted the angular menu system as well as haptic feedback for users to comfortably carry out the gesture as well as not being distracted by the feedback of hotkey presses like audio or visual. We designed a more effective way of haptic feedback to use the minimal attention from the user to carry out the function. It was found from the informal user evaluation the Hapick could improve the current way of inputting hotkeys and significantly reduce the burden on hand, wrist and shoulder.

INTRODUCTION

The more advanced software developed, the more complicated the hotkey became. For instance, many design software has various functions to execute, which makes it very cumbersome for the users to find the tap on the toolbar. This made the users to be seated at the desk with computers and suffer from fatigue and pain on their wrist due to the continuous usage of keyboard and mouse.

This situation was improved by the invention of hotkeys. Hotkeys refer to the keyboard press combinations which carry out a function. However, although the input became infrequent, it still required user to use their left hand on the keyboard and restricted users' sitting positions. It also built a burden on their eyes as they have to context switch from monitor to keyboard for complicated hotkey combinations. Hence, freeing their left hand from the keyboard when they do not necessarily need to use the keyboard apart from hotkeys would be beneficial to many users with hotkeys.

We explore a design idea of a feet-worn device. Many attempts have been made with feet as it was known to support simple tasks which could aid under hand-busy situation. We adapted the angular menu system which utilizes the simple feet movement as menu selection. For the user to understand which menu that they are on, we adapted haptic feedback. Haptic feedback was found to be less effective than visual or audio under angular menu system. Hence, we attempted redesigning this feedback for the user to recognize it well and also not be distracted. We expect this prototype could successfully solve the current input method of hotkey and remove burden on the body.

RELATED WORK

The study regarding the wearable user interface about the hotkey presses were very underdeveloped. There were few studies that also aimed to solve the cumbersome of hotkey presses. [1] and [2] is the hotkey presses which utilize the usage of finger gestures. To simplify hotkey presses, [1] used touch interaction on each key, and [2] used finger recognition. [3] used the gesture on the trackpad for the hotkey presses. They are all effective approaches that made the usage of hotkey easier. However, they all could not remove the need of using their left hand. Specifically, all of the three studies require the usage of both hands. This does not completely solve the fatigue problem of users.

Many body parts can handle work under hand-busy environment. Out of these, [4] found out that the feet could provide an alternative to the hands for the input, as the feet has both power as well as control. This is why there is a wide variety of feet-based devices like [5]. These kinds of wearable system designed many feet interactions as the input to the digital devices. Although there has been very little attempt to connect these with hotkey presses, we could find some feet gesture that were used in wearable interface.

The previous study on feet gestures, [6] shows that the two gesture of feet that showed the similar performance was toe rotation and heel rotation. This is the reason why there are multiple studies done on the angular menu selection, which uses the rotation of the feet for selecting a certain menu.

[7] shows the angular menu selection using the heel rotation. It was activated by lifting the forefoot up, rotating the forefoot, and pushing the forefoot down to select. They used visual feedback for the user to recognize which menu that they are on. [8] shows the angular menu selection as well. They utilized haptic feedback; when they move their feet from one menu to the next, a discrete haptic feedback of short buzz was felt. However, it was found that the haptic feedback showed lower accuracy than audio.

Although visual and audio feedback has higher accuracy, they distract people heavily. Hence, Hapick removed the need for visual or audio and redesigned the haptic as the continuous one to solve the current way of hotkey input.

HAPICK

Hapick is the foot-worn device which can simplify the hotkey input using the angular menu method. It also utilized haptic feedback for user to select the appropriate hotkey.

HARDWARE IMPLEMENTATION

In the process of idea development, we considered two ways for hotkey input – knees and toes. Although both seemed to have potential according to the user survey conducted, we decided to use foot-based input since using the knee would add another device to be worn. The simplified diagram of hardware design is shown in Figure 1 and Figure 2. The equipment used include ESP32 Board (WEMOS LOLIN32 Lite), IMU sensor, 2 FSR Sensor, 4 Vibration Motor Module, LiPo Battery and Jumper Wires.

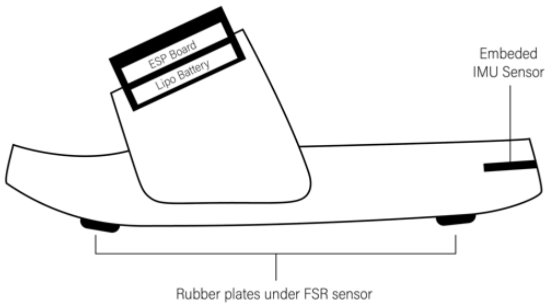

Figure 1. Side View of Hapick

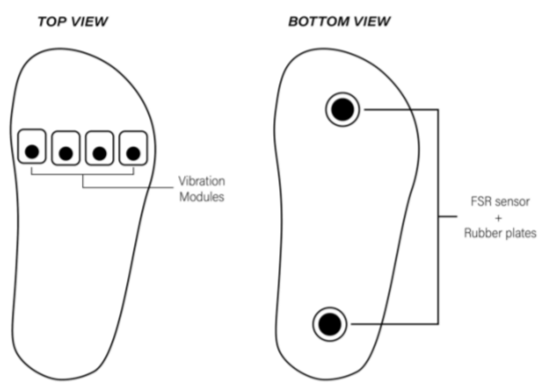

Figure 2. Top and Bottom View of Hapick

Hotkey Selection

The method of angular menu selection is used for the hotkey selection. We initially considered dual rotation technique – providing both toe and heel rotation to support users' comfortable sitting positions. However, this would worsen the usability as the ranges of angle to rotate are different for each rotation. This would make the interaction confusing as the users have to remind themselves which direction they would have to rotate. Hence, we simplified the interaction by only allowing rotation of the heel. To detect the angle of rotation, an IMU sensor was embedded in the heel part of slipper shown in Figure 1.

Haptic Feedback

For the haptic feedback to aid hotkey selection, we initially planned to place the vibration modules along the inner vamp of the slipper, allowing the vibration to be felt at the dorsum of the foot. However, considering the various size of shoe and shape of feet, it would not be possible that the dorsum of foot is in contact with the shoe in all cases. Thus, we implanted four vibration modules at the sole portion of the slipper as shown in Figure 2, so that vibration can be felt at the bottom of user's foot. Since vibration modules would not vibrate as much when fixed hard on a surface, a piece of sponge was placed between the slipper and the modules. In addition, we made sure that the modules faced inwards the foot for a clear contact with the foot.

Hotkey Input

The activation of hotkey input and confirmation of hotkey selection is done by applying pressure to the toe and the heel part of feet respectively. These gestures were detected by FSR sensor, thus placed at the bottom of slipper as shown in Figure 2. As FSR sensors do not work well on flat surfaces, a small rubber plate is placed under the FSR, so that the force can be applied to the center of sensor.

SOFTWARE IMPLEMENTATION

To compensate for drifts in gyro values of the IMU sensors to calculate the rotation angle of the feet, we used the Madgwick filter. In addition, BLE keyboard library was utilized to send hotkey input to the computer through Bluetooth according to the sensor values of foot position.

Hotkey Selection

The initial settings of angular selection of menu consists of four most commonly used hotkeys. These hotkeys were chosen according to the survey conducted with KAIST Industrial Design students who uses design software frequently. These are Ctrl + Z, Ctrl + C, Ctrl + V, and Ctrl + S. As shown in Figure 3, there is one option to the right, and 3 options to the left since rotating inwards is more comfortable for rotation of the heel. We set the left-most module to Ctrl +Z, so that if there are any false positives, this action can be taken comfortably. It also relates to the action of going back one step. Moreover, the most recent hotkey input is saved. Hence, when the next input is activated, the selection starts from that hotkey. This was intended to accommodate a repeated hotkey input. We set the range of angle for each hotkey options to 15 degrees as it was the most suitable and comfortable angle for the users.

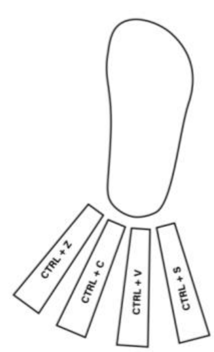

Figure 3. Hotkey Selection Menu

Hotkey Algorithm

1. Activate the device by applying force to the front part of the feet.
2. Pivoting the front part of the feet, rotate your heel for hotkey selection. You will feel a vibration as a haptic feedback in a range of angles for each option, corresponding to the order of hotkey options set.
3. When the selection is done, apply force to the heel. This will input the corresponding hotkey.

USER STUDY

Due to the time constraint, we conducted informal user study to see how users can adapt to Hapick and check its effectiveness. There were 5 participants and 2 of them were KAIST students majoring in industrial design.

Procedure

We first spent sufficient amount of time to teach each participant how to use the product. Afterward, the user was given 10 minutes as the learning time. We gave Microsoft PowerPoint for them to play with the product. Then, the user testing was conducted. With an object already drawn on the screen, the participants were asked to copy the object, paste the object, undo the action, and save the file. We have made observations during the process.

Results

Overall, we could find out the potential benefit that Hapick can bring to the users, although there were some learning curves. At first, the participants had to view the serial monitor to get used to the angle of rotation. This was because they were unfamiliar with the haptic feedback. They also had to memorize which hotkey will be pressed on each feedback. In addition, although they successfully could input the hotkeys, they were not sure about how much pressure must be applied for activation and confirmation. However, after a few trials, they all realized that it is unnecessary to apply too much pressure.

After the time has passed 10 minutes, all of the participants got used to the product. We could say that the average learning time that takes for our product is about 10-15 minutes maximum. Four of the participants have said that the gesture was very intuitive and easy. One of the participants had said memorizing the hotkey mapping took some time, but got easier after experimenting.

During the test, it was seen that the participant could quickly achieve the simple task given. Three participants finished the task within 10 seconds and two participants in 20 seconds. It was seen that the time taken with our product was similar to that of using hands. Since the product was mapped to a very simple hotkeys, we could expect that for difficult hotkey combinations, the product will actually provide very efficient and effective input method.

It was also seen that the rate of making mistakes with our product was higher than using hands. This was inevitable for simple hotkey combinations. However, as we mapped Ctrl+Z at the very left, it could be quickly undone.

Overall, their feedback on the usage was that it requires some time to get used to it, and they also said it is a good way to free the burden of one hand. One of the participants also commented that as it gets the feet moving a bit, it might allow blood circulation along the leg that has been slowed down due to prolonged sitting time.

DISCUSSION

Most input systems are dependent on visual and auditory cues nowadays. Visual cues, which are dominant feedback mechanisms, are chosen because of their accurate information transfer. However, as computer system develops, multiple-input systems started to conflict and competed against it. Therefore, the need for dispersing feedback mechanisms other than the visual cue is inevitable for both accuracy and usability. In project Hapick, an alternative input system distinguished as haptic feedback showed clear advantages in this context. Hapick relieves the burden for hands in the workspace without the conflicts with visual cues by having vibration motors as the substitute. Unlike prior works taken for hotkey inputs, Hapick allows a complete hands-free method while having comparable accuracy and time-taken. This input method equipped with a new design of effective ways of haptic feedback opens room for a parallel input system allowing more efficient human-computer interaction.

Future Work

Hapick project accurately transferred angular menu selection for hotkey input. However, there are room for improvements. Hardware is the main limitation of our project. Due to size of vibration modules, number of menu selection was limited only to 4. Using smaller vibration modules, menu variation can be widened and usefulness might increase. Elsewise, the activation could be varied by pressing the forefoot twice to activate another set of hotkeys for Hapick to support more hotkey combinations.

Using the new interaction technique of Hapick, continuous input systems could be developed. Not only in selecting discrete menus, this new haptic feedback design can be used on a slider-based input. Overall, haptic feedback mechanism will be very effective in handling complex user input systems and environments that they are in.

CONCLUSION

We propose Hapick, a device that allows users to interact with a computer through the foot-worn controller. This approach relieves the hand and wrist fatigues created from the continuous wait of infrequent hotkey inputs without adding another burden for users' eyes to track the feedback. The angle of rotation and the overall gesture was designed from multiple user studies taken. People felt rotating their heels more comfortable than others. We tested 5 users who had no experience in wearable input devices with haptic feedback. The majority of them successfully performed preassigned jobs with accuracy and speed comparable to those done by traditional hand jobs. We conclude Hapick to be a potential substitute for future input systems.

REFERENCE

1. *Yilei Shi, Haimo Zhang, Hasitha Rajapakse, Nuwan Tharaka Perera, Tomás Vega Gálvez, and Suranga Nanayakkara. 2018. GestAKey: Touch Interaction on Individual Keycaps. In Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems (CHI '18). Association for Computing Machinery, New York, NY, USA, Paper 596, 1–12. https://doi.org/10.1145/3173574.3174170*

2. *Jingjie Zheng and Daniel Vogel. 2016. Finger-Aware Shortcuts. In Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems (CHI '16). Association for Computing Machinery, New York, NY, USA, 4274–4285. https://doi.org/10.1145/2858036.2858355*

3. Wenzhe Cui, Jingjie Zheng, Blaine Lewis, Daniel Vogel, and Xiaojun Bi. 2019. HotStrokes: Word-Gesture Shortcuts on a Trackpad. In Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems (CHI '19). Association for Computing Machinery, New York, NY, USA, Paper 165, 1–13. https://doi.org/10.1145/3290605.3300395

4. *Eduardo Velloso, Dominik Schmidt, Jason Alexander, Hans Gellersen, and Andreas Bulling. 2015. The Feet in Human--Computer Interaction: A Survey of Foot-Based Interaction. ACM Comput. Surv. 48, 2, Article 21 (November 2015), 35 pages. https://doi.org/10.1145/2816455*

5. *Xavier Benavides, Chang Long Zhu Jin, Pattie Maes, and Joseph Paradiso. 2015. KickSoul: A Wearable System for Feet Interactions with Digital Devices. In Adjunct Proceedings of the 28th Annual ACM Symposium on User Interface Software & Technology (UIST '15 Adjunct). Association for Computing Machinery, New York, NY, USA, 83–84. https://doi.org/10.1145/2815585.2815730*

6. *Jeremy Scott, David Dearman, Koji Yatani, and Khai N. Truong. 2010. Sensing foot gestures from the pocket. In Proceedings of the 23nd annual ACM symposium on User interface software and technology (UIST '10). Association for Computing Machinery, New York, NY, USA, 199–208. https://doi.org/10.1145/1866029.1866063*

7. *Kang Zhong, Feng Tian, and Hongan Wang. 2011. Foot Menu: Using Heel Rotation Information for Menu Selection. In Proceedings of the 2011 15th Annual International Symposium on Wearable Computers (ISWC '11). IEEE Computer Society, USA, 115–116. https://doi.org/10.1109/ISWC.2011.10*

8. J. Anlauff, T. Kim and J. R. Cooperstock, "Feel-a-bump: Haptic feedback for foot-based angular menu selection," *2018 IEEE Haptics Symposium (HAPTICS)*, 2018, pp. 175-179, doi: 10.1109/HAPTICS.2018.8357172.