Keyboard Clawing: Input Method by Clawing Key Tops

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Abstract. We present a directional and quantitative input method by clawing key tops, Keyboard Clawing. The method allows a user to input a direction and quantity at the same time without moving his/her hands much from the keyboard's home position. As a result, the user can seamlessly continue typing before and after inputting the direction and quantity. We found that clawing direction is classified using clawing sounds with an accuracy of 68.2% and that our method can be used to input rough quantity.

Keywords: keyboard, acoustic sensing, gesture, input method.

1 Introduction

Some researchers have proposed input methods using keyboards in order to provide seamless inputs while typing. Block et al. presented a touch-display keyboard [1], which recognizes user's hands movements by touch sensors attached under each key top and provides a graphical display on its surface. This allows a user to use the keyboard like a touch-display. Tsukada et al. suggested a PointingKeyboard [2], which allows users to perform pointing on the keyboard by recognizing the user's hands position using an IR sensor attached on the keyboard. However, these approaches need keyboards to be modified significantly, thus they are expensive to realize.

Unlike these approaches, Keyboard Clawing, our input method, uses *sounds caused by clawing key tops* to detect a user's operation to allow four-directional input with quantity. It recognizes the direction in which the user claws key tops and distance of clawing by analyzing the sounds. This method has the following three advantages.

1. A user can input a direction and quantity at the same time using a keyboard.
2. A user can begin the input fast because the user can claw key tops without moving his/her hands much from the home position.
3. The system is inexpensive to realize because it only needs one microphone to be attached to a keyboard the a user is accustomed to using.

We begin with the previous work on input methods by extending keyboards' input capability or using acoustic sensing. Next, we explain the design and implementation of our Keyboard Clawing and its applications. Finally, we refer to a user study that shows users' performance of our method.

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2 Related Work

There are some input methods using keyboards other than mentioned above. Dietz et al. proposed a practical pressure-sensitive keyboard [3] that could detect pressure information of key pressing. Fallot-Burghardt et al. presented an extended keyboard, Touch&Type [4], which allows users to use the keyboard surface for touchpad-like pointing. Rekimoto proposed the ThumbSense [5]. ThumbSense senses contact of user's finger to the touchpad. Under this condition, a user can click by pressing a normal key (e.g., *F*) instead of click buttons. This allows a user to click without moving his/her hands from the keyboard's home position. Keyboard Clawing also extends keyboards' input capability. In contrast to these previous approaches, our method uses clawing sounds on the keyboard to detect users' operations.

Many approaches using acoustic sensing to detect users' operations have been proposed [6–10] . Keyboard Clawing also uses acoustic sensing. Our method differs from these approaches in terms of using *clawing sounds on the keyboard* to detect a user's operation.

Researchers have also classified the sounds to detect gestures on keyboards. Zhuang et al. [11] and Berger et al. [12] distinguish pressed keys by analyzing typing sounds. Kato et al. presented Surfboard [13], which allows a user to perform two-directional input without quantity. Surfboard uses sounds produced by a user's large hand movements on the keyboard. Since Surfboard only needs a microphone, it is realized at low cost. Keyboard Clawing also uses sounds on keyboards to detect gestures on them but provides four-directional and quantitative input to users.

3 Keyboard Clawing

In this section we explain how to use Keyboard Clawing. A user puts his/her hands in a keyboard's home position and claws the key tops with his/her finger to up, down, right, or left (Figure 1). If a user wants to input up or down, he/she claws the key tops in either direction with his/her index finger. If a user wants to input right or left, he/she claws the key tops in either direction with his/her thumb. Note that this design intends to reduce the movement of the user's hand from a keyboard's home position.

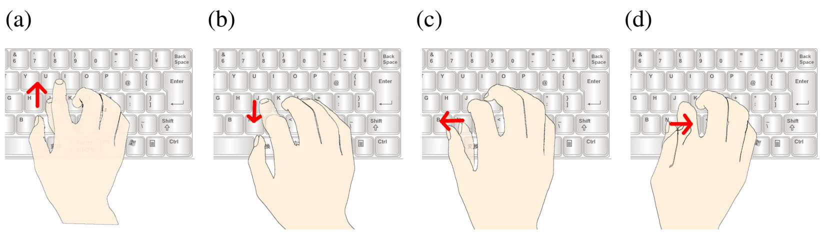


Fig. 1. How to claw key tops in Keyboard Clawing. If a user wants to input up or down, he/she claws key tops to each direction by his/her index finger (a, b). If a user wants to input right or left, he/she claws key tops to each direction by his/her thumb (c, d).

The system uses the clawing sounds for detection of clawing direction and distance. Specifically, the distance is the number of grooves between keys the user claws. A user measures the clawing distance at a rough estimate to input quickly. For example, when the user claws *J* to *N*, the system recognizes the input as "1-down". When the user claws *M* to *B*, the system recognizes the input as "2-left".

4 Implementation

To recognize how a user claws key tops using the clawing sounds, we attach a piezo microphone (Shadow SH-710, Figure 2) on a keyboard (Dell KB212-B, Japanese keyboard) to capture the sounds (sampling rate: 96 kHz, quantization bit rate: 16 bit) as shown in Figure 3. The system first scales the captured sounds from -1.0 to 1.0 and then reduces noise of the scaled sounds using MMSE-STSA [14]. When the system detects a peak exceeding a threshold (0.3), it regards the sound as a clawing one and recognizes the clawing direction and distance by analyzing the sounds. The system also monitors the key release events in order to distinguish the clawing sounds from typing sounds. If the system detects the sounds 500 *ms* after the key release events occur, it regards the sounds as typing sounds. not clawing ones.

Fig. 2. Piezo microphone

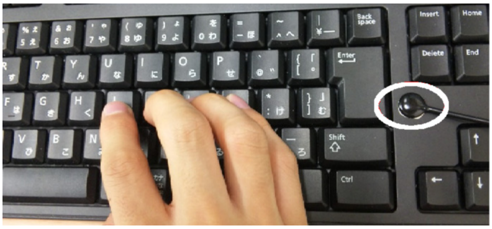


Fig. 3. Piezo microphone on a keyboard

4.1 Detecting the Direction

We use frequency distribution of the clawing sounds in order to detect the clawing direction. The system obtains a frequency distribution of the 2000 samples (20.8 ms) centered of the sounds' first peak using the Fast Fourier Transform (FFT). The FFT frame size is 2000. This results in 1000 feature values (band: 0 - 48 kHz). The clawing sounds are classified using the feature value and a support vector machine (SVM) as a discriminator.

4.2 Detecting the Distance

We use the number of peaks of the clawing sounds in order to detect the clawing distance because a peak occurs when the user claws key tops and the finger passes on a groove between keys. We first extract 48000 samples (500 ms) and transform the sounds by taking the absolute amplitude of each sample. Then, we compute the simple moving average of each transformed sample for 50 periods (Figure 4d) to remove stray peaks and smooth the waveform. Next, the system scans the smoothed waveform and counts the number of samples that exceed threshold (0.12) (Figure 4e). In scanning, the system ignores peaks within 2000 samples (20.8 *ms*) from a sample exceeding the threshold because the peaks are considered to be caused by clawing the same groove of the previous peak.

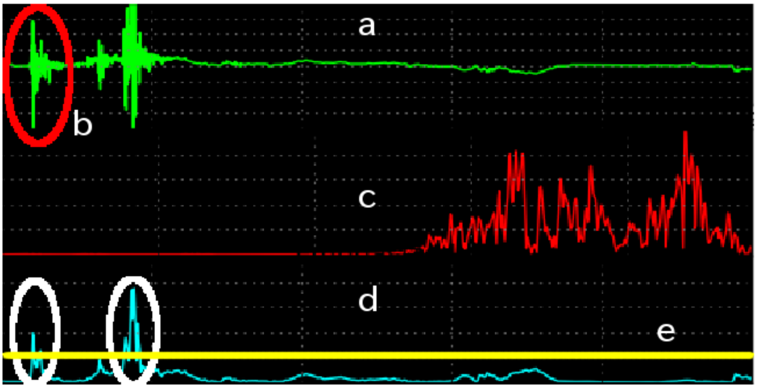


Fig. 4. (a) Example clawing sounds waveform. (b) First peak used for direction detection. (c) Frequency distribution of the example sounds. (d) Smoothed waveform. (e) Threshold of distance.

5 Applications

We used Keyboard Clawing for shortcuts in word processing, in which direction and quantity are frequently input.

Text selection and changing the font size: We use our Keyboard Clawing to select text and change the font size. Table 1 shows an example of functions assigned to our method. Figure 5 shows how one uses our method.

Scrolling: We also apply our Keyboard Clawing to scrolling. Table 2 shows an example of functions assigned to our method. Figure 6 shows how one uses our method. A user cannot only adjust input quantity but also change function by clawing distance (e.g., 1-down: scroll a line. 2-down: scroll a page).

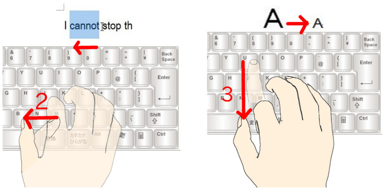
In these cases, a user can select text or change the font size or scroll without moving his/her hands from the keyboard's home position, unlike keyboard shortcuts or pointing devices, so that he/she can seamlessly continue typing before and after the operation.

Table 1. Example of functions assigned to Keyboard Clawing

Direction\Distance	1	2	3
Up	font size +5pt	font size +10pt	font size +15pt
Down	font size -5pt	font size -10pt	font size -15pt
Left	select a left character	select a left word	select to top of the line
Right	select a right character	select a right word	select to end of the line

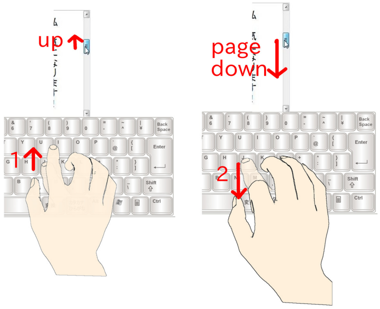
Table 2. Example of scroll functions assigned to Keyboard Clawing

Direction\Distance	1	2	3
Up	1 line up	1 page up	to top
Down	1 line down	1 page down	to end



(a) (b)

Fig. 5. Text selection and changing font size by Keyboard Clawing. (a)Select a left word. (b)Scale-down 15pt.



(a) (b)

Fig. 6. Scrolling by Keyboard Clawing. (a) Upwards 1 line. (b) Downwards 1 page.

6 Evaluation

To examine the accuracy of detecting clawing direction and distance, we conducted a user study in a quiet room. We recruited 12 volunteer participants (11 male and one female) aged from 22 to 24 years. One participant made too many mistakes in the study, thus we use data from the other 11 participants. Their nails were of ordinary length.

Before the study, participants were told how to use Keyboard Clawing and practiced till they were accustomed to the method. Participants were able to ask an experimenter about the method or the study during the practice. To prevent loss of concentration, they could also take a rest between tasks freely.

In a trial, the participants were told both direction and quantity. The quantities were 1-4 in clawing to up or down, and 1-10 in clawing to left or right. Each participant conducted trials five times in each direction and quantity and thus performed $(4 \times 2 + 10 \times 2) \times 5 \times 11 = 1,540$ trials. We only showed visual feedback to inform participants that the system had detected the sounds. Note that Keyboard Clawing is intend to allow users to input quickly, thus we suppose that when one uses the method he/she measures the clawing distance as a rough estimate. Hence, we told participants to follow the indicated quantity roughly.

7 Results and Discussion

7.1 Accuracy of the Distance

Table 3 shows the accuracy of the distance. The results show low accuracy (between 19.6% - 39.5%). There are two reasons for this. First, when the clawing finger touches a key top, a peak occurs if the user touches it strongly but not if the user touches it softly. Second, participants follow the indicated distance roughly.

To study the accuracy further, we adopt a tolerance. In clawing to up and down, the accuracies were 98.2% and 90.5%, respectively, when the tolerance was two. Similarly in clawing to left and right, the accuracies were 91.5% and 89.6%, respectively, when the tolerance was three. Thus, the results are highly accurate for the tolerances of two and three. Hence our method is applicable to inputting a rough quantity.

Table 3. Accuracy of the distance (%)

Direction \ Tolerance	0	1	2	3	4
Up	39.5	83.6	98.2	100.0	100.0
Down	37.3	75.0	90.5	100.0	100.0
Left	24.4	58.5	80.2	91.5	96.9
Right	19.6	54.7	76.2	89.6	95.6

7.2 Accuracy of the Direction

To obtain the accuracy of the direction, we extracted the feature of the participants' clawing sounds and then conducted a 35-fold cross-validation. To classify, we use a SVM provided by the Weka Machine Learning toolkit [15]. The SVM type was C-SVC, the kernel type was linear kernel, the cost value was 512.0, the gamma value was 0.000125, and we set "Normalize" true.

Table 4. Accuracy of direction of the per-user test (%)

Input \ Classified as	Up	Down	Left	Right	Accuracy
Up	**60.5**	14.1	15.9	9.5	60.5
Down	12.7	**62.3**	13.2	11.8	62.3
Left	4.9	2.7	**72.6**	19.8	72.6
Right	2.4	3.5	16.7	**77.4**	77.4
Average	-	-	-	-	68.2

Table 5. Accuracy of direction of the cross-user test (%)

Input \ Classified as	Up	Down	Left	Right	Accuracy
Up	**41.8**	22.7	23.2	12.3	41.8
Down	24.5	**46.4**	12.3	16.8	46.4
Left	10.0	7.5	**56.9**	25.6	56.9
Right	4.4	4.5	25.3	**65.8**	65.8
Average	-	-	-	-	56.4

In per-user test, we conducted the cross-validation to each participant's feature value. Table 4 shows detailed results of the per-user test. The average in all directions is 68.2%. Table 5 shows a confusion matrix of cross-user test. In the cross-user test, we conducted the cross-validation to all participants' feature values. The average in all directions is 56.4%. This result shows we can classify the clawing directions by frequency distribution of the sounds with accuracy of about 70%. The result of cross-user test was 56.4%, 11.8 points lower than that of the per-user test. This means that the clawing sounds differ among users. Hence, before using our method actually, users need calibration. We also found that the accuracy of left or right clawing is higher than that of up or down clawing. This is because left or right clawing is louder than up or down clawing, thus the features of sounds appear clearly.

7.3 The Number of Key Pressing in Clawing

To study whether it is rational to monitor key release events in order to distinguish the clawing sounds from typing sounds, we also examine *the number of key pressings (NKP)* in clawing. Table 6 shows detailed *NKP*, and Figure 7 shows maps of pressed keys in each directional clawing in the study. In these maps, the more times a key is pressed in clawing, the darker the key is colored. The results show participants tended to press keys when clawing large distances and in the latter part of clawing, thus the system failed to distinguish clawing sounds from typing sounds. To solve this problem, we will use the previous sounds. Even if key release events occur, the system will regard the sound as a clawing one if the clawing sounds occurred just previously.

Table 6. Detailed *NKP* (%)

Direction \ Distance	1	2	3	4	5	6	7	8	9	10	Average
Up	1.8	0.0	3.6	1.8	-	-	-	-	-	-	1.8
Down	0.0	0.0	0.0	0.0	-	-	-	-	-	-	0.0
Left	0.0	0.0	1.8	3.6	5.5	7.3	14.6	9.1	16.4	18.2	7.6
Right	3.6	1.8	1.8	0.0	1.8	3.6	1.8	9.1	10.9	7.3	4.2
Average	1.4	0.5	1.8	1.4	3.6	5.5	8.2	9.1	13.6	12.7	4.5

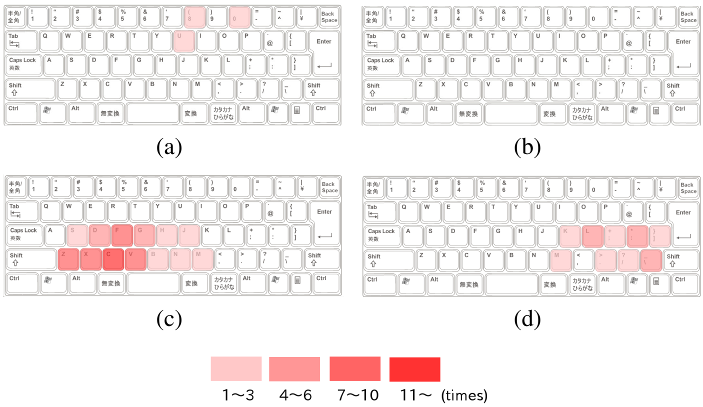


Fig. 7. Maps of pressed keys in each directional clawing. (a) Up. (b) Down. (c) Left. (d) Right.

8 Conclusions and Future Work

We presented a directional and quantitative input method by clawing key tops, Keyboard Clawing. The system detects the sounds caused by clawing key tops without user's hands moving much from the keyboard's home position. Keyboard Clawing enables a user to continue typing seamlessly before and after clawing. We conducted a user study and found the accuracy of the direction to be 68.2% for each participant, thus the algorithm needed to be improved. Additionally, the accuracy of distance is approximately 90% with a tolerance of two or three, thus our method is applicable to inputting a rough quantity.

For future work, we want to improve the detecting direction algorithm. We have two plans for new algorithms. In one, although we used only the first peak to detect the direction, we will apply the SVM classifier to all peaks in a clawing sound and then adopt a direction that detected the most as an input direction. In the other, we will adopt time series analysis using Hidden Markov Models. After improving the algorithm, we also want to compare our method with other input methods (e.g., keyboard shortcuts, mouse pointing) in terms of input speed and error rate to confirm the effectiveness of Keyboard Clawing.

References

1. Block, F., Gellersen, H., Villar, N.: Touch-display keyboards: transforming keyboards into interactive surfaces. In: Proceedings of the 28th International Conference on Human Factors in Computing Systems, CHI 2010, pp. 1145–1154 (2010)
2. Tsukada, Y., Hoshino, T.: PointingKeyboard:An input device for typing and pointing. In: Proceedings of Workshop on Interactive Systems and Software, WISS 2002, pp. 999–99 (2002) (in Japanese)
3. Dietz, P., Eidelson, B., Westhues, J., Bathiche, S.: A practical pressure sensitive computer keyboard. In: Proceedings of the 22nd Annual ACM Symposium on User Interface Software and Technology, UIST 2009, pp. 55–58 (2009)
4. Fallot-Burghardt, W., Fjeld, M., Speirs, C., Ziegenspeck, S., Krueger, H., Läubli, T.: Touch&type: a novel pointing device for notebook computers. In: Proceedings of the 4th Nordic Conference on Human-Computer Interaction: Changing Roles, NordiCHI 2006, pp. 465–468 (2006)
5. Rekimoto, J.: ThumbSense: automatic input mode sensing for touchpad-based interactions. In: CHI 2003 Extended Abstracts on Human Factors in Computing Systems, CHI EA 2003, pp. 852–853 (2003)
6. Murray-Smith, R., Williamson, J., Hughes, S., Quaade, T.: Stane: synthesized surfaces for tactile input. In: Proceedings of the Twenty-Sixth Annual SIGCHI Conference on Human Factors in Computing Systems, CHI 2008, pp. 1299–1302. ACM (2008)
7. Harrison, C., Hudson, S.: Scratch input: creating large, inexpensive, unpowered and mobile finger input surfaces. In: Proceedings of the 21st Annual ACM Symposium on User Interface Software and Technology, UIST 2008, pp. 205–208 (2008)
8. Harrison, C., Schwarz, J., Hudson, S.: TapSense: enhancing finger interaction on touch surfaces. In: Proceedings of the 24th Annual ACM Symposium on User Interface Software and Technology, UIST 2011, pp. 627–636 (2011)
9. Lopes, P., Jota, R., Jorge, J.: Augmenting touch interaction through acoustic sensing. In: Proceedings of the ACM International Conference on Interactive Tabletops and Surfaces, ITS 2011, pp. 53–56 (2011)

10. Harrison, C., Xiao, R., Hudson, S.: Acoustic barcodes: passive, durable and inexpensive notched identification tags. In: Proceedings of the 25th Annual ACM Symposium on User Interface Software and Technology, UIST 2012, pp. 563–568 (2012)
11. Zhuang, L., Zhou, F., Doug, T.: Keyboard acoustic emanations revisited. ACM Transactions on Information and System Security 13(1), 1–3 (2009)
12. Berger, Y., Wool, A., Yeredor, A.: Dictionary attacks using keyboard acoustic emanations. In: Proceedings of the 13th ACM Conference on Computer and Communications Security, CCS 2006, pp. 245–254 (2006)
13. Kato, J., Sakamoto, D., Igarashi, T.: Surfboard: keyboard with microphone as a low-cost interactive surface. In: Adjunct Proceedings of the 23nd Annual ACM Symposium on User Interface Software and Technology, UIST 2010, pp. 387–388 (2010)
14. Ephraim, Y., Malah, D.: Speech enhancement using a minimum mean-square error short-time spectral amplitude estimator. IEEE Transactions Acoustic Speech & Signal Processing 32, 1109–1121 (1984)
15. Hall, M., Frank, E., Holmes, G., Pfahringer, B., Reutemann, P., Witten, I.H.: The WEKA data mining software: an update. Explorations Newsletter 11(1) (2009)