Perception of Delay in Computer Input Devices Establishing a Baseline for Signal Processing of Motion Sensor Systems

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Abstract. New computer input devices in healthcare applications using small embedded sensors need firmware filters to run smoothly and to provide a better user experience. Therefore, it has to be investigated how much delay can be tolerated for signal processing before the users perceive a delay when using a computer input device. This paper is aimed to find out a threshold of unperceived delay by performing user tests with 25 participants. A communication retarder was used to create delays from 0 to 100 ms between a receiving computer and three different USB-connected computer input devices. A wired mouse, a wifi mouse and a head-mounted mouse were used as input devices. The results of the user tests show that delays up to 50 ms could be tolerated and are not perceived as delay, or depending on the used device still perceived as acceptable.

Keywords: Computer mouse · Delay · Embedded systems · Healthcare · Perception · USB

1 Introduction

Developing firmware without hindering users to perform tasks in their ability is of importance for small wearable sensor systems, especially in healthcare applications. Early developed gyroscope based computer head mice [1] and similar systems need filtering and smoothing of sensor data to work properly, as sensors used in wearable systems are appreciated to be small, light, cheap and usually have the drawbacks of high sensitivity to environmental disturbances [2,3]. Signal processing and its resulting delay are main factors on system performance.

In the previous research, system latency has already been seen as a primary concern in providing real-time interaction for human-computer interfaces [4]. The effect of delay in the quality of video and voice communication [5], in video

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streaming [6], between visual information and tactile information [7], in haptic environments [8] have been analyzed. Unnoticeable delay of approximately 150 ms for keyboard interactions and up to 195 ms for mouse interactions were found by detecting changes in a graphical user interface [9].

Moreover, to investigate how long calculations and filters can run in the firmware of an embedded device, studies have been conducted to find out the user perception of unperceived, acceptable, disturbing and unacceptable delays. Previously, research has been performed to investigate the first indicator on how delay between 0 and 500 ms was perceived by users. With a common computer mouse, delays up to 150 ms have been demonstrated as acceptable delay, while delays over 300 ms were regarded as unacceptable and delays between 150 ms and 300 ms were perceived by users as disturbing [10]. The results provided a baseline on the limit of acceptable delay for data processing in microprocessors, embedded systems or other similar applications. However, more thoroughly studies are needed to investigate the interval below 100 ms delay and to consider the effect of using different USB input devices.

The aim of this paper was to better understand the user's perception of delay when using different input computer devices and to find out a more precise baseline allowing to set a limit for signal processing in small embedded sensor systems. Therefore, we performed user tests with 25 participants who tested three different computer input devices with settings of 0 ms, 25 ms, 50 ms, 75 ms and 100 ms of delay in alternating order for each input device. This paper focuses on (1) How much delay can be set until users perceive the delay? (2) What is the difference when using different computer input devices with divergent sensitivity? (3) Is there a difference between interaction methods, such as hand movement or head movement?

2 Research Approach

To change the values of delay in a controlled way, the communication retarder as described in [10] was used to generate delays. Software was developed to perform a click task for users and to collect user data. A wired computer mouse with USB cable, an USB wifi mouse and a head-mounted mouse called MultiPos were connected to the communication retarder called USB-delay. An overview of the test setup can be seen in Fig. 1.

To collect user feedback and data for evaluations and investigations, user tests were performed during 2 days with 25 persons, 22 male and 3 female participants, from the age of 24 to 52 with an average age of 34.7. All participants were daily computer users without mobility impairment. Most users (22/25) were using a computer mouse daily. The other 3 users were using a trackpad for daily uses. Most users had never used a head-mounted mouse before. Only one user tested a head movement controlled game.

The hardware for our tests, shown in Fig. 1, consisted of a gaming laptop (MSI MS-16GF) with Windows 10, an in-house developed communication retarder (USB-delay device), a gaming mousepad (Logitech G240), a wired gaming mouse

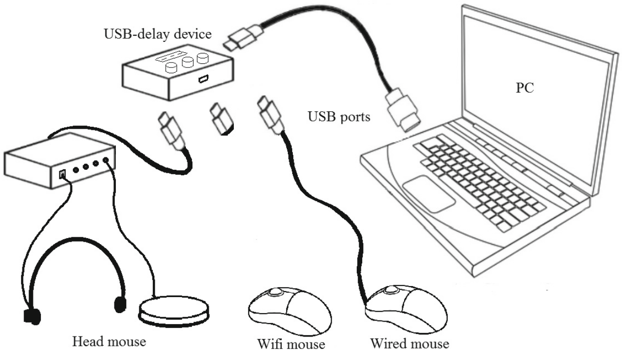

Fig. 1. System overview.

(Logitech M500), a wifi mouse (Packard Bell MORFEOUO) and a MEMS gyroscope based head-mounted computer mouse (MultiPos).

At the beginning of each test, the testers were informed about the purpose of the study, their tasks and the procedure. Each user tested three different devices for 5 rounds with 5 different delay values. The users' task was to click on 4 emerging images on the screen with unknown but fixed locations in each round. As done in the previous research, the order was chosen to start with a neutral setting of 0 ms, giving the testers a baseline of the mouse sensitivity and time to adapt to the tests [10]. Then the delay between higher and lower settings was alternated. In order to gather information about the users' experiences, a questionnaire was required to be answered. The perceived level of delay that the user perceived was asked in the form of choosing a score between four perceived levels: (1) 'unacceptable', (2) 'disturbing', (3) 'acceptable' and (4) 'no delay perceived'. After every round the users rated their experience with the device at the set delay value. Additionally, data was collected on how long it took the users to click on the emerging images and if users were able to click the images through our developed software. The collected data and the feedback from the users was then analysed with the help of MATLAB.

3 Results and Discussion

The results of our evaluations and the user feedbacks are described statistically in Fig. 2. Here, the amount of feedback is presented by different sized red points in combination with a number, reflecting the users' questionnaire choices. The blue curve connects the majority levels and shows the main trend of the perceived results. For the wired mouse the delay of 50 ms can be seen as the threshold value between 'no delay perceived' and 'acceptable'. In other words, the delays smaller than 50 ms were not perceived by the users using the wired mouse. The tests and evaluation also show that the delay perception of the users is affected by the sensitivity of the USB devices. With a low sensitivity wifi mouse,

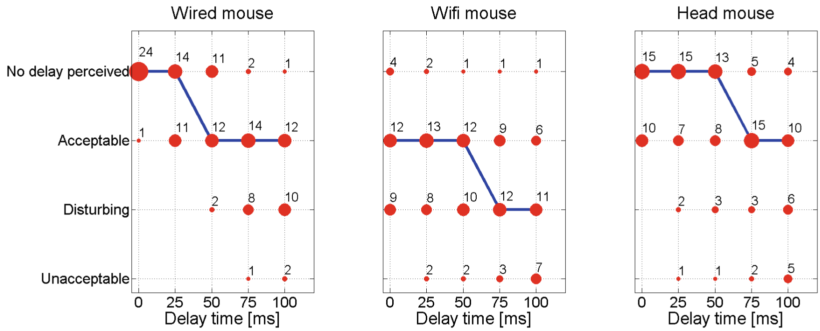

Fig. 2. User perceived feedback. (Color figure online)

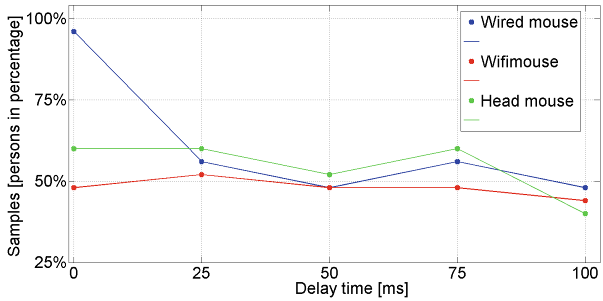

Fig. 3. Majority distribution. (Color figure online)

50 ms of delay can still be seen as threshold value, but scored a lower perception rating between 'acceptable' and 'disturbing'. The head-mounted mouse has more sensitivity because of a more precise MEMS gyroscope. Here, more users did not perceive delays up to 50 ms in comparison to the other two devices.

Figure 3 presents the majority distribution of the three different devices used in this research. The blue curve depicts the results of the wired computer mouse, while the red one presents for the wifi mouse and the green curve is for the head-mounted mouse. Almost 100% of the users (24/25) gave the same feedback for the delay of 0 ms with the wired mouse. In the continuation of the comparison, more than 50% of the users had similar opinions for the delays of 25 ms, 50 ms, 75 ms and 100 ms, respectively. For the head-mounted mouse, except the delay of 100 ms, around 60% of the users showed similar perceptions with the delays of 0 ms, 25 ms, 50 ms and 75 ms. For the wifi mouse, around 50% of the users perceived similar results with all five delay values. In general, users showed the most different perceptions with the wifi mouse.

The elapsed time for clicking the four images in each round was recorded in our software. The data was averaged by images and users. The average clicking time of the different delays from 0 ms to 100 ms is 1.56 s with the wired mouse, 1.87 s with the wifi mouse and 2.22 s with the head-mounted mouse. The trends

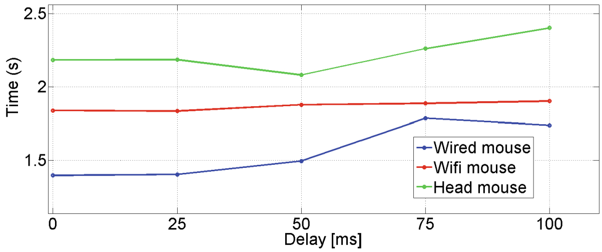

Fig. 4. Elapsed time. (Color figure online)

of elapsed time for the three different devices are depicted in Fig. 4. The blue curve presents the results of the wired mouse, the red curve is for the wifi mouse and the green curve shows the results for the head-mounted device. The elapsed time to click on the images is increasing as the delay increases. As shown with the red curve, the users needed more time to click on the images with larger delays. The green curve shows that it takes more time to click on the images with the head-mounted mouse. Less elapsed time with the delay of 50 ms reflects that the users might have adapted to the movements after the first round. However, they still spend more time as the delay increases afterwards.

Table 1. Overview of missed images during the tests.

Delay (ms)	0	25	50	75	100	Sum
Mouse	-	1	1	2	-	4
Wifi mouse	2	5	2	3	3	15
Head mouse	8	19	4	21	24	76
Sum	10	25	7	26	27	95

During the tests 1500 images were clickable in total (25 users × 3 devices/user × 5 rounds/device × 4 images/round). The images disappeared after 3 s in case a user could not click on it. Totally 95 missed images were recorded during the test, 22 for first appearing image, 22 for the second image, 33 for the third image and 18 for the fourth image. Table 1 shows the number of missed images with different delay values and devices. As shown in Fig. 4 and Table 1, generally it took users the most time and the most misses happened when using the head-mounted mouse, while the least time and misses happened when using the wired mouse. In general, we can say that the greater the delay is, the more time to click on the images was needed and the more misses happened.

4 Conclusion

A previous study has shown the effects of USB-delay on a broad delay range from 0 ms to 500 ms [10]. In this paper, we have further investigated the effects of delay in three different computer input devices and provided a more detailed investigation into how much delay is not perceivable to users. Through user tests with 25 participants, it was found that a delay up to 50 ms was not perceived as delay for most tested devices and users. This value provided a threshold value that we see as a limit for signal processing in embedded systems, especially body-worn or computational healthcare systems such as head-mounted computer mice. The sensitivity of a device, previous experiences and what users are used to, affected their perceptions. These individual differences amongst users could for example be seen with a simple, less sensitive wifi mouse, as users rated their experience with lower scores. Using an uncommon and unknown technology of a MEMS gyroscope based head-mounted computer mouse, users needed more time to click on appearing images as users needed to move their heads in comparison to the hand-controlled mice. Nonetheless, the perceived results were even better with a delay of 50 ms or less, in comparison to computer mice due to the high sensitivity of the MEMS gyroscope.

References

1. Gerdtman, C., Bäcklund, Y., Lindén, M.: A gyro sensor based computer mouse with a USB interface: a technical aid for motor-disabled people technology and disability. Technol. Disabil. **24**(2), 117–127 (2012)
2. Du, J., Gerdtman, C., Lindén, M.: Signal processing algorithms for temperature drift in a MEMS-gyro-based head mouse. In: 21st International Conference on Systems, Signals and Image Processing, pp. 123–126. IEEE Press (2014)
3. Du, J., Gerdtman, C., Lindén, M.: Noise reduction for a MEMS-gyroscope-based head mouse. In: 12th International Conference on Wearable Micro and Nano Technologies for Personalized Health, pp. 98–104. IOS Press (2015)
4. Carlson, J., Han, R., Lao, S., Narayan, C., Sanghani, S.: Rapid prototyping of mobile input devices using wireless sensor nodes. In: 5th IEEE Workshop on Mobile Computing Systems and Applications, pp. 21–29. IEEE Press (2003)
5. Kurita, T., Iai, S., Kitawaki, N.: Assessing the effects of transmission delay - interaction of speech and video. In: 14th International Symposium: Human Factors in Telecommunications Proceedings, pp. 111–121 (1993)
6. Bhamidipati, V.D., Kilari, S.: Effect of Delay/Delay Variable on QoE in Video Streaming. Master thesis, School of Computing at Blekinge Institute of Technology (2010)
7. Miyasato, T., Noma, H., Kishino, F.: Subjective evaluation of perception of delay time between visual information and tactile information. IEICE Trans. Fundam. Electron. Commun. Comput. Sci. **79**(5), 655–657 (1996)
8. Rank, M., Shi, Z., Müller, H.J., Hirche, S.: Perception of delay in haptic telepresence systems. Presence **19**(5), 389–399 (2010)
9. Dabrowski, J.R., Munson, E.V.: Is 100 milliseconds too fast? In: CHI 2001 Extended Abstracts on Human Factors in Computing Systems, pp. 317–318 (2001)
10. Du, J., Kade, D., Gerdtman, C., Özcan, O., Lindén, M.: The effects of perceived USB delay for sensor and embedded system development. In: Proceedings of the 38th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, pp. 2492–2495. IEEE Press (2016)