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Acknowledgement of Incoming Call of Smartphone in Silent Mode Walking at Flat Ground, Up-and-down Stairways

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ABSTRACT: This paper investigates whether incoming call of carried smartphone is noticed in silent mode, using acceleration data obtained from the smartphone. Prototyped application calculates norm of three-axis (x, y and z) of acceleration data obtained from acceleration sensor in smartphone and variation amplitude in absolute value of difference between the norm value and 1G. In experiment, relation between the variation amplitude and the incoming call notice in silent mode was measured in most of moving conditions; walk on flat ground and up-and-down stairways at slow (3.2 km/h), normal (4.8 km/h) and fast (6.0 km/h) speed, respectively. Measurement was also conducted in standing condition for reference and comparison. Smartphone was possessed in subject's pocket. Experimental result showed that 17 subjects-averaged variation amplitudes were 0.39 m/s^2 and notice rate were 99.89 % in rest conditions. 17 subjects-averaged variation amplitude were 2.07, 3.47 and 4.35 m/s^2 in walk on flat ground, 4.85, 5.77 and 6.40 m/s^2 in walk-up stairways, and 4.68, 7.05 and 8.49 m/s^2 in walk-down stairways, respectively at slowly, normal and fast speed. Also, 17 subjects-averaged notice rate were 49.06, 30.00 and 11.11 % in walk on flat ground, 12.56, 0.56 and 0.00 % in walk-up stairways, and 14.11, 0.50 and 0.22 % in walk-down stairways, respectively at slowly, normal and fast speed. From the result, when user did not answer incoming call though he noticed the call (vibration) in silent mode, it is presumed that the user did not answer intentionally if the variation amplitude is less than roughly 2 m/s^2 (slowly walk). On the other hand, it is presumed that the user just did not notice the call if the variation amplitude is more than roughly 2 m/s^2 (slowly walk). These result and conclusion is expected of application to development of re-notification application when user did not notice incoming-call in silent mode.

Keywords: Incoming call, notice, silent mode, smartphone, walking speed.

1 INTRODUCTION

In recent years, according to widespread of smartphone, almost smartphone user set silent mode at public space, particularly crowded environments seen often in Japan. It then has became problem that the user often dose not notice vibration of the silent mode informing call incoming [1]. There are some counter-measures in terminal itself, such as strengthening vibration and changing vibration waveform [2]. On the other hand, outside of terminal, there are electronic tools built in bracelet (wrist watch) and head set, which connects smartphone through Bluetooth communication and notice user incoming call through the bracelet and head set [3]. In this research, a method as application implemented in smartphone itself is proposed, in order to avoid adding external equipment for cost and trouble in wearing those devices. Figure 1 shows a functional flow chart of the proposed system for noticing user incoming call when there is no answer to incoming call, under silent mode. The system judges that user did not notice incoming call when any operation is not performed in a period of time after incoming call. The system then estimates user's moving status from a moving average of acceleration data, and gives a vibration for re-notification to user when the system judged a timing from the user's moving status, in which the user definitely notices the re-notification vibration when the moving average of acceleration data is less than a threshold. The system judges goal achievement and return its status to initial phase (start), when there is an operation by the user within a period of time after the re-notification from the system. However, there is not any operation, the system judges that the user did not notice the re-notification and repeats monitoring acceleration data, provides re-notifications, and waits operation of the user.

This paper experimentally investigates relation between the user's notice of the incoming call (vibration) and acceleration data, during walking on flat ground and up-and-down stairways. This paper finally concludes whether the relation between the user's notice and the acceleration data can be used for the proposed system as system parameters.

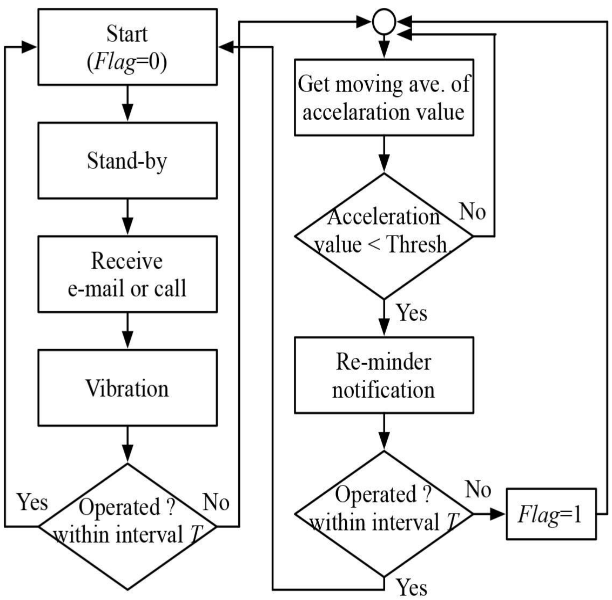


Figure 1: Flowchart of Proposed System.

2 METHODS

2.1 Experimental method

Figure 2 shows a functional diagram of the experimental system consisted of smartphone and laptop-PC. Nexus 5 (LG, Android 4.4.4) was used for smartphone. An application for the smartphone was prototyped for obtaining time and three-axis (x, y and z) of acceleration data from acceleration sensor at four samples per second in each axis, and stores into database system SQLite. The SQLite database can be used without use of network and can be directly implemented into application as one of library, and is widely used as database system for smartphone in which light burden is required [4].

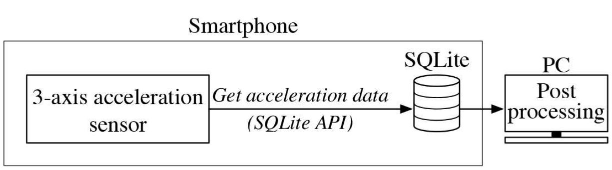


Figure 2: Configuration of Experimental System

Figure 3 shows display of the prototyped application in which three-axis of acceleration data and calculated norm of the three-axis acceleration data are shown on its display. After experiment, the smartphone was connected to the laptop-PC and transmitted those data from the SQLite database into the PC. The norm of the three-axis acceleration data was used as representative acceleration value in order to reduce effects caused by difference in directions and angles of the sensor attached on body, and also by difference of walking form depending on each subjects [5]. The norm was calculated as following formula:

$$N_a(t) = \sqrt{x_a(t)^2 + y_a(t)^2 + z_a(t)^2} \qquad (1),$$

where $x_a(t)$, $y_a(t)$ and $z_a(t)$ are the acceleration values of the x, y and z-axis respectively, and $N_a(t)$ is the norm of the acceleration values of the three-axis.

Figure 3: Example of Display of Smartphone Application in Experimental System

Recent smartphone built-in acceleration sensor outputs 9.8 m/s^2 (1 G), that is earth gravity acceleration value, at standing condition. Direction and angles of the smartphone then can be measured from the three-axis acceleration values

2.2 Subjects

For basic and simple investigation this time, selected subjects were seven-teen males of university students (20-25 years old) who were good in health, in order to reduce effect due to individual difference. Subjects received explanation of the experiment aim and outline in a document and oral, and signed a written approval about handling experiment data. Subjects also managed physical conditions by appropriately getting meal and alcohol, sleeping time, the day before the experiment.

2.3 Task

Subjects walked in most of moving conditions; walk on flat ground and up-and-down stairways at slow (3.2 km/h), normal (4.8 km/h) and fast (6.0 km/h) speed, respectively [6]. Measurement was also conducted in standing condition for comparison.

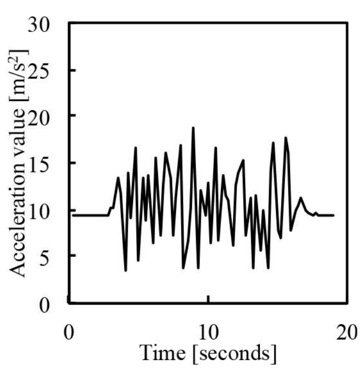
Walking distance in each task was 20 meters in which required time to walk was 12 seconds at the fast speed and was enough to measure notice of incoming call. Smartphone holding location was subject's front pocket of pants because of mostly used location.

2.4 Measurement of incoming-call notice

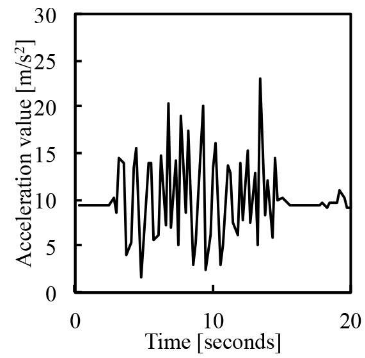
Each subject conducted acceleration measurement under ten conditions, which were three kinds of walking locations (flat ground and up-and-down stairways) with three kind of walking speed (slow, normal and fast) and just standing. After the each measurement, subject graded visual analog scale (VAS) from 0 (not noticec at all) to 100 (clearly noticed) with a questionnaire sheet. Reason of use of the VAS evaluation is that the notice often depends on a conscious level toward the incoming call and becomes unclear even in standing condition. Subjects dose not notice the call sometimes even in standing condition.

3 RESULT

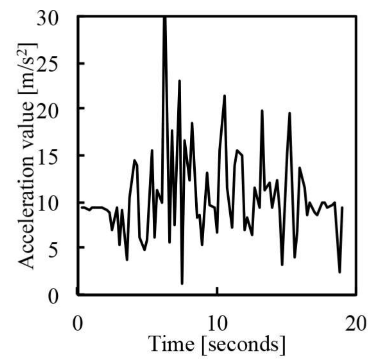
Figures 4 (a), (b), (c) and (d) show examples of variation of acceleration value in time, which were norm of the three-axis of acceleration values, when walking on flat ground (slowly, fast), down-stairs (slowly), and up-stairs (slowly), respectively. The acceleration values at around start and end time areas were almost constant and equals to 1G, that means reliability of data acquisition. It is figured out that swing of the acceleration data norm becomes large in order of walking on flat ground slowly [fig. 4(a)] , fast [fig. 4(b)], down-stairs slowly [fig. 4(c)], and up-stairs slowly [fig. 4(d)]. In this research, relative swing, that is absolute value of difference of the acceleration data norm and 1G, was used for criteria of notice estimation.



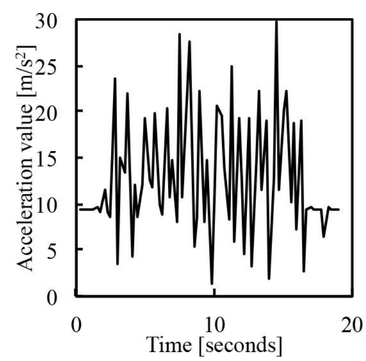
(a) Walk on Flat Ground (Slowly)



(b) Walk on Flat Ground (Fast)



(c) Walk Down Stairs (Slowly)



(d) Walk Up Stairs (Slowly)

Figure 4: Examples of Acceleration Data Norm

Figures 5 and 6 show 17-subject average of the relative acceleration data norm and incoming-call acknowledgment respectively, when walking on flat ground, down stairs, and up stairs, respectively at speed of slow, normal and fast. In those figures, error range means standard error. Table 1 also shows summary of the relative acceleration data norm and VAS of the incoming-call acknowledgement with standard error, respectively. Result in standing condition is also shown for reference and comparison. It is figured out that the relative acceleration data norm increases in order of walking on flat, walking down and up stairs, as previously described in fig 4. Also in each walking condition, the relative acceleration data norm increases in order of slow, normal and fast for walking speed. The acknowledgement of the incoming-call became low as the relative acceleration data norm increased. Averaged acknowledgement was 50 % (standard error was 8.58), even when walking on flat ground in which the averaged relative acceleration data norm was lowest (2.07 m/s^2), that means half-and-half mixed feeling for incoming-call or nothing. Furthermore, acknowledgement rate was not 100 % in just standing condition. Consequently, it was figured out that user dose not notice incoming-call (vibration) in silent mode even when concentrating on call incoming.

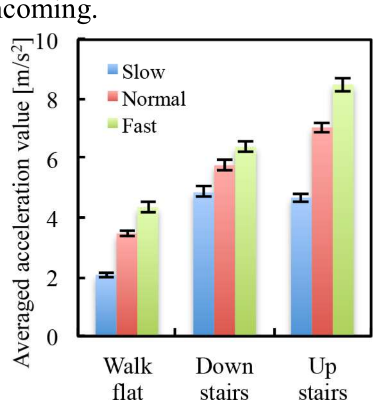


Figure 5: Relative Acceleration Data Norm (17 Subject Averaged)

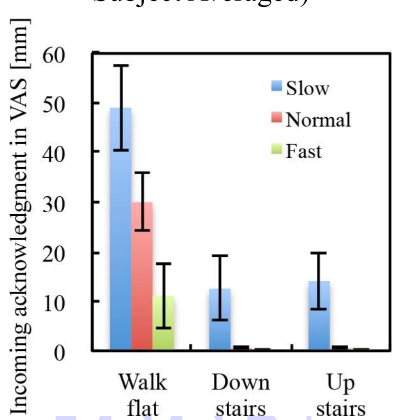


Figure 6: VAS of Incoming-Call Acknowledgement (17 Subject Averaged)

Table 1 Relative Acceleration Data Norm and Acknowledgement (17 Subject Averaged)

		Relative acceleration data norm $\|N_a\text{-}1G\|$ (standard error) [m/s^2]	VAS of incoming-call ack. rate (standard error) [mm]
Rest		0.39 (0.05)	99.89 (0.11)
Walk on flat	Slow	2.07 (0.08)	49.06 (8.58)
	Normal	3.47 (0.12)	30.00 (6/14)
	Fast	4.35 (0.17)	11.11 (3.91)
Walk down stairs	Slow	4.85 (0.18)	12.56 (5.69)
	Normal	5.77 (0.19)	0.56 (0.32)
	Fast	6.40 (0.17)	0.00 (0.00)
Walk up stairs	Slow	4.68 (0.15)	14.11 (6.53)
	Normal	7.05 (0.17)	0.50 (0.40)
	Fast	8.49 (0.23)	0.22 (0.22)

4 DISCUSSION

Acknowledgement rate decreased in accordance with walking speed increasing. This was because periods of vertical and horizontal vibration became short and comes near that of vibration in silent mode, as walking speed increases. In walking up-and-down stairs, movement of legs became large and thus acceleration increasing significantly decreased acknowledgement rate, comparing with walking on flat ground. The relative acceleration data norm in walking up stairs became larger than that in walking down stairs, because of large movement in raising legs up in walking up stairs that decreased the acknowledgement rate of the in-coming call.

As goal of this research, that is, it was figured out that the relative acceleration norm might be able to be used as a criterion for judgement whether user acknowledges incoming-call (vibration) in silent mode. Threshold of the judgement shown in proposed system can be set from 0.39 (standing) to 2.07 (walking slowly on flat ground). However, when near 0.39 is set as the threshold value, almost of user might have to stand still for the re-notification form the proposed system. In the other hand, when near 2.07 is set as the threshold value, the user received the re-notification repeatedly when walking slowly on flat ground, then might not notice the re-notification, and loop of the re-notification might be iterated in half-and-half of possibility. It is not purpose of this research but is figured out that the relative acceleration data norm make possible distinguishing three kinds of walking status, that are walking on flat ground, up stairs, and down stairs.

5 CONCLUSION

This research experimentally investigated the relation between the acknowledgement of incoming-call (vibration) under silent mode and the acceleration data obtained from smartphone built-in acceleration sensor, for walking smartphone user. Relative acceleration norm data, that is absolute value of difference between norm of three-axis acceleration data and 1G was used as a criterion. For walking speed of slow (3.2 km/h), normal (4.8 km/h) and fast (6.0 km/h), experimental result showed that 17-subject-averaged relative acceleration data norm were 2.07, 3.47 and 4.35 m/s^2 when walking on flat ground, 4.85, 5.77 and 6.40 m/s^2 when walking up stairs, and 4.68, 7.05 and 8.49 m/s^2 when walking down stairs, respectively. At that time, the acknowledgement rates were 49.06, 30.00 and 11.11 % when walking on flat ground, 12.56, 0.56 and 0.00 % when walking up stairs, and 14.11, 0.50 and 0.22 % when walking down stairs, respectively. Standing still condition also provided 0.39 m/s^2 of relative acceleration data norm with 99.89 % of acknowledgement rate. Thus, the relative acceleration data norm might be able to be used as a criterion for judgement whether user acknowledges incoming-call in silent mode. Threshold of the judgement might be able to be set from 0.39 (standing) to 2.07 (walking slowly on flat ground). The acknowledgement was slightly different from subjects and the threshold should be self-adjustable.

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