Suguden Sensor Motion

Technology Reports

Tapless Phone Operations by Natural Actions! —Suguden Functions—

*NTT DOCOMO has developed "Suguden" functions that enable a user to operate a phone using only natural actions without having to touch the screen. This article describes the Suguden mechanism for determining user actions using only sensors that are typically installed in Android™ *1 smartphones. It also describes a method for achieving similar operability among different phone models despite sensor-dependent output values.*

Communication Device Development Department *Kiichi Ishibashi*
Shigeru Ochi
Product Department *Satoru Kawamura*
Shunsaku Yamazaki

1. Introduction

The proliferation of smartphones in recent years has made screen tapping a routine way of operating a phone. Nevertheless, there are still situations in which screen tapping is difficult or impossible to perform. Tapping operations are particularly inconvenient to users who want to answer an incoming call immediately but cannot tap the screen because their other hand is tied up with carrying a handbag or briefcase, their fingertips are wet, etc. In addition, making a call with a smartphone requires a greater number of taps compared with a feature phone, which can also be a source of inconvenience. NTT DOCOMO has responded to this issue by developing "Suguden" functions that enable a user to operate a phone using only natural actions without having to tap the screen. These original functions were first installed in the 2016 summer models of NTT DOCOMO smartphones.

In this article, we first explain the Suguden mechanism for determining user actions using only sensors that are typically installed in Android devices. We then describe a method for achieving similar operability despite differences in sensor output values that vary by phone model.

2. Overview of Suguden

Suguden enables the user to perform the following basic phone operations without having to tap the screen (**Figure 1**).

(1) Call: The user can make a call by simply shaking the phone and holding it up to an ear. One calling destination (person) may be registered for each left/right ear. First, shaking the phone one time displays a calling dialog (**Figure 2**). The previously set calling destinations are displayed at this time enabling the user to check what is currently registered for each ear and to make a call by holding the phone up to the appropriate ear (The 2016 winter models enable calling destinations to be set from the

*1 **Android™:** A Linux-based open source platform developed by Google Inc. in the United States targeting mainly mobile information terminals. A trademark or registered trademark of Google Inc. in the United States.

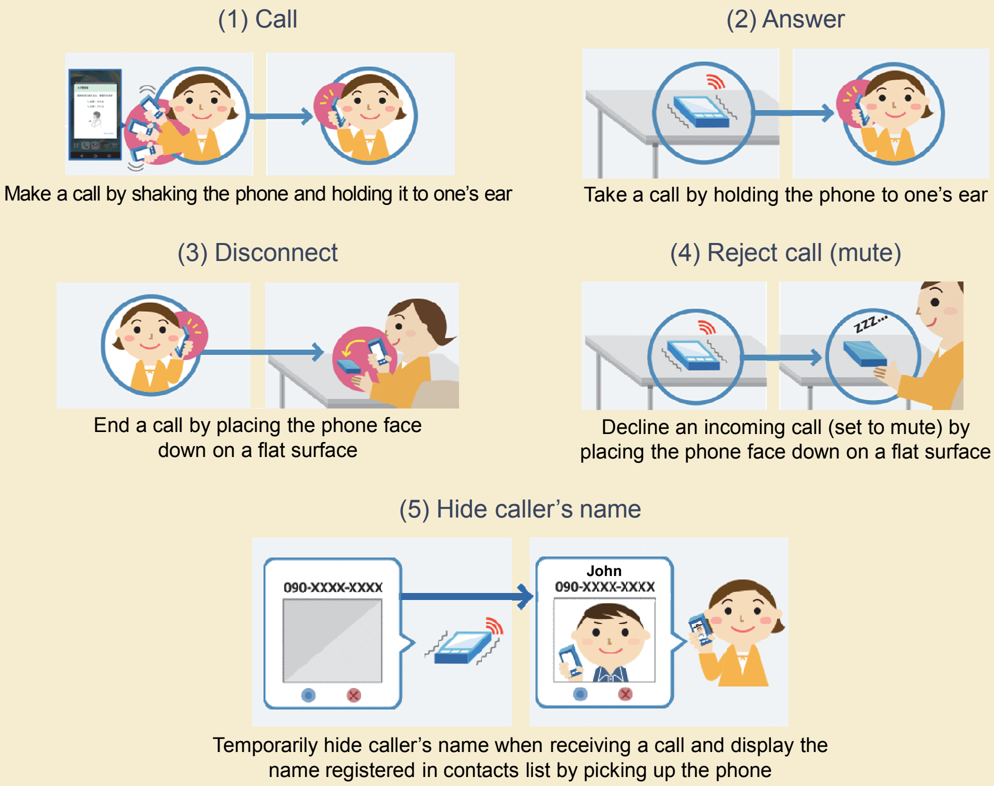

Figure 1 Overview of Suguden functions

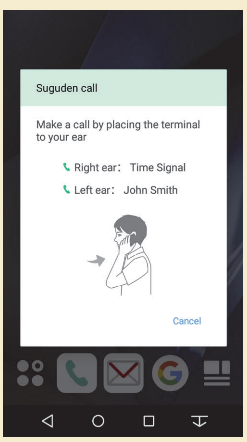

Figure 2 Calling dialog

user's call history).

(2) Answer: The user can answer an incoming call by simply holding the phone up to an ear.

(3) Disconnect: The user can end a call by placing the phone facedown

on a desk or shaking it twice (supported from 2016 winter models).

(4) Reject call (mute): The user can decline an incoming call by placing the phone facedown on a desk or shaking it twice (supported from 2016 winter models). The specific type of reject-call operation to be performed at this time may be selected from "mute," "reject," and "reject and send SMS."

(5) Hide caller's name: There are times when the user does not wish surrounding people to see the name of the caller at the time of an incoming call such as when the phone is sitting on a table in full view during a meeting. Envisioning such a scenario, this function disables display of the caller's name from the user's contacts list at the time of an incoming voice or video call. The user can then display the name by picking up the phone or simply moving it.

3. Suguden Algorithm

A conceptual diagram of Suguden operations is shown in **Figure 3**. The Suguden application, which is separate from the phone application, receives notifications on call state from the phone application and initiates/terminates motion*2 detection. Suguden motion detection is accomplished by combining data from a proximity sensor*3, acceleration sensor*4, and gyro sensor*5. Here, a standard Android Application Programming Interface (API)*6 is used to obtain sensor data, which makes any revisions to Android itself unnecessary and enables the Suguden application to be used in nearly all Android smartphones. In addition, we observed a variety of user behavioral cases with the aim of using natural actions to perform phone operations such as call, answer, disconnect, and reject call. Furthermore, given that handset shape, sensor-installation position, sensor specifications, etc. can differ between smartphone models, motion-detection thresholds are adjusted for each model and stored as a parameter file to enable uniform detection of each type of motion. This parameter file is supported from the 2016 summer models on.

The following describes the detection algorithm for each type of motion.

3.1 Phone-to-ear Motion (Call/answer Operations)

We examined the actions of actual users in studying an appropriate algorithm to adopt. In the call operation, it was often observed that the user would bring the phone up to the chest after shaking it to check the calling dialog on the screen. In the answer operation as well, there were many cases in which the user would bring the phone up to the chest at the time of an incoming call to check the identity of the caller.

For the above reasons, it was decided to detect the action (motion) of bringing the phone up to the ear using the

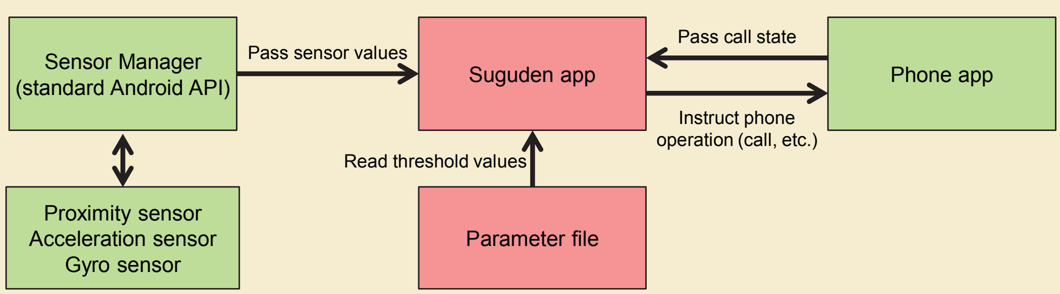

Figure 3　Conceptual diagram of Suguden operation

*2 **Motion:** Action associated with a user terminal operation.

*3 **Proximity sensor:** A sensor that detects contact with or closeness to an object.

*4 **Acceleration sensor:** A sensor that measures changes in speed. Equipping a mobile terminal with an accelerometer allows it to sense orientation and motion.

*5 **Gyro sensor:** A sensor that measures angular velocity. Installing a gyro sensor in a mobile terminal enables change in velocity in the rotational direction to be measured.

*6 **API:** An interface that makes the functions provided by the OS, middleware and other such software available to upper-level software.

position of the chest as base point. Furthermore, to enable the selection of not one but two calling destinations by allowing the user to hold the phone up to the left or right ear, it was decided to detect which ear the user was using to make a call.

Based on the above user actions, each type of motion is detected by determining phone movements as described below.

The sequence for detecting the motion of bringing the phone up to an ear is shown in **Figure 4** (a) and the definition of the phone's coordinate axes for use as reference is shown in **Figure 5**.

(1) After recognizing an opportunity to initiate motion detection (call: at time of calling dialog display; answer: at time of incoming voice call), the Suguden application activates the gyro, acceleration, and proximity sensors.

(2) Suguden uses the gyro sensor to detect the user action of holding the phone up to an ear. First, motion is detected in step (2)–1, and next, the locus of the phone approaching an ear is measured in step (2)–2 to detect that the phone has been brought next to that ear.

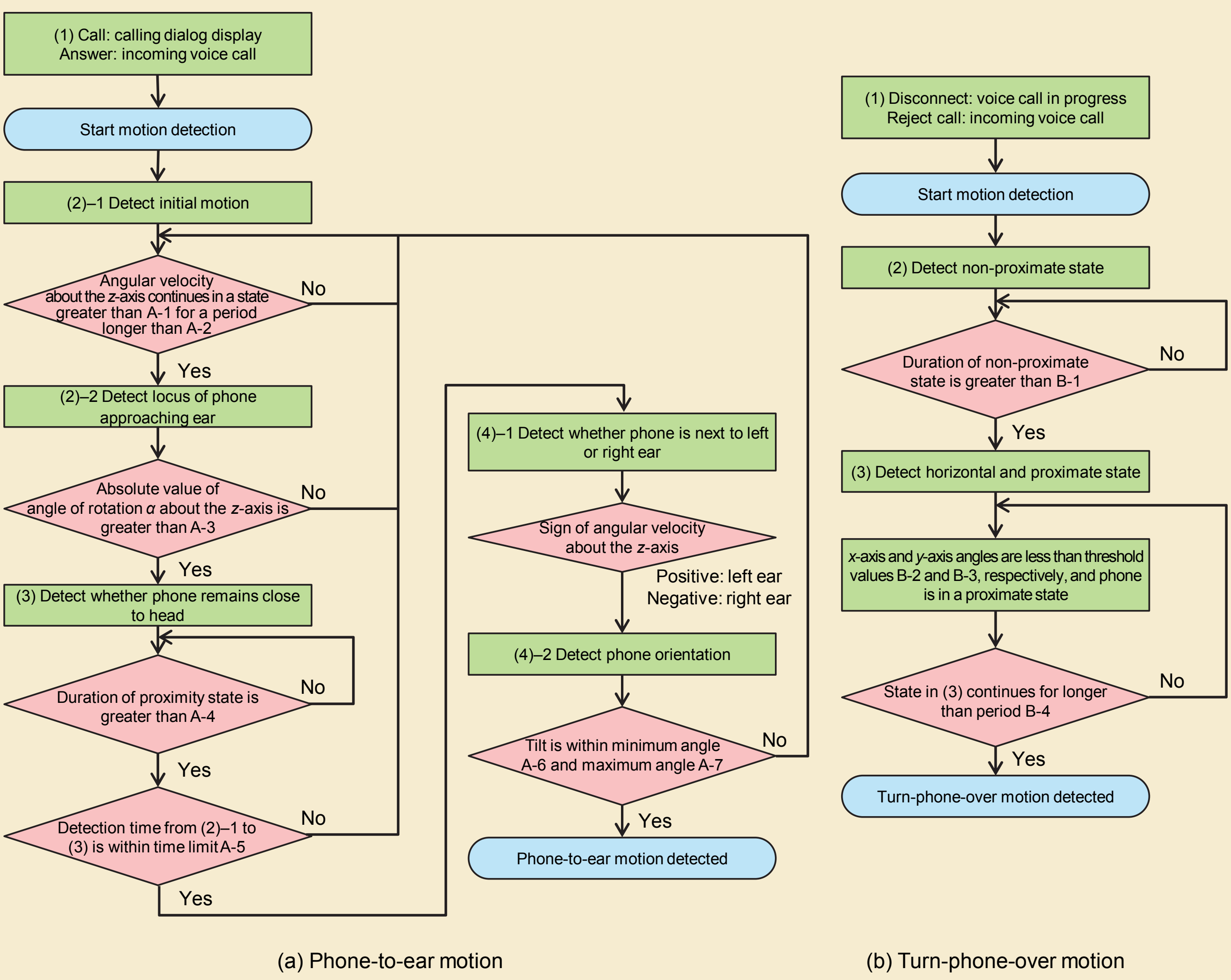

Figure 4 Motion sequence

(2)–1: Detect initial motion of phone

In the event that the *x*–*y* surface is rotated about the origin (phone center), this step uses the gyro sensor to determine whether an angular velocity greater than threshold A-1 continues for longer than period A-2. Furthermore, to exclude phone movement within a handbag, briefcase, etc. the proximity sensor is used to check whether the phone is in a non-proximate state during period A-2.

(2)–2: Detect movement from initial motion to holding phone up to ear

This step calculates the absolute value of angle of rotation α about the *z*-axis from detection time (2)–1 by taking the time integral of the angular velocity obtained from the gyro sensor and checks whether that value is greater than threshold A-3. If below the threshold, the flow returns to decision (2)–1 above. (**Figure 6** (a)).

(3) Suguden uses the proximity sensor to check whether the phone brought near an ear remains close to the user's head. If the proximity state continues for period

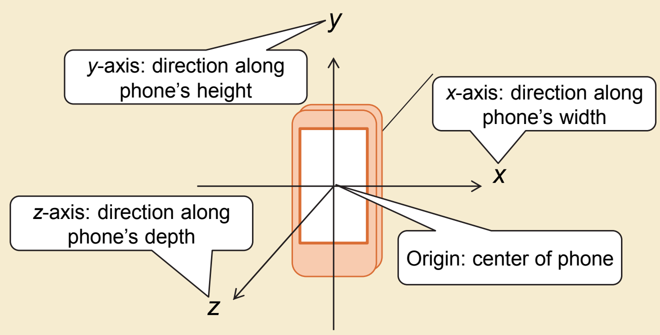

Figure 5 Reference coordinate axes

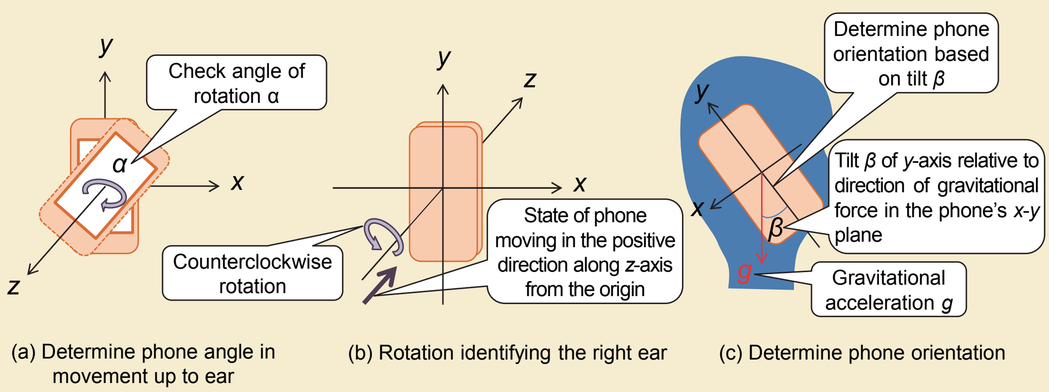

Figure 6 Detection of phone-to-ear motion

A-4, the flow advances to decision (4). If detection time from (2)–1 to (3) is longer than time limit A-5, the flow returns to decision (2)–1 above.

(4) Suguden uses the acceleration sensor to determine whether the phone has been brought close to the left or right ear and checks whether the final orientation of the phone is appropriate in terms of its tilt angle when held up against the ear.

(4)–1: This step determines whether the phone has been brought up to the left or right ear based on the direction of its rotation (clockwise/counterclockwise) when in a state moving in a positive direction from the origin along the *z*-axis at decision time.

Condition for right ear (Fig. 6 (b)): rotation about the *z*-axis is counterclockwise, that is, angular velocity about the *z*-axis < 0

Condition for left ear: rotation about the *z*-axis is clockwise, that is, angular velocity about the *z*-axis > 0

(4)–2: This step determines the orientation of the phone with respect to the ear (left or right) determined in step (4)–1 (Fig. 6 (c)).

Tilt of *y*-axis in the phone's *x*-*y* relative to gravitational acceleration *g* is taken to be β. This step checks whether β lies within a range of threshold values (minimum angle A-6, maximum angle A-7). Since the phone's sensor cannot detect β directly, this check compares g_x, g_y calculated by the following expressions based on threshold values with g_x, g_y detected from the phone's sensor (g_x, g_y are the *x*-axis and *y*-axis components of gravitational acceleration *g*).

Right ear:

$g_x = g \cdot \sin \beta$,

$g_y = g \cdot \cos \beta$

Left ear:

$g_x = g \cdot \sin (-\beta)$,

$g_y = g \cdot \cos (-\beta)$

If the above matches the conditions up to step (4)–2, that action is considered to be a motion that brings the phone up to the left or right ear.

3.2 Turn-phone-over Motion (Disconnect/reject-call Operations)

It often happens in a disconnect operation that the user moves the phone away from the ear and places it on a desk, table, or some kind of surface. In such a case, proximate and non-proximate operations in the form of proximate (next-to-ear state), non-proximate (away-from-ear state), and proximate (on-surface state) are repeated in a short time period, so we here designed the algorithm so that the phone state at this time could be correctly detected using the proximity sensor.

Meanwhile, in a reject-call operation, it often happens that the user first brings the phone in front of the chest to check the identity of the caller and then places the phone on a desk, table, or some kind of surface. For this reason, we designed the algorithm so that the motion of placing the phone on a surface could be detected using the non-proximate state as base point.

The sequence for detecting the turn-phone-over motion is shown in Fig. 4 (b).

(1) After recognizing an opportunity to initiate motion detection (disconnect: at time of voice call; reject call: at time of incoming voice call), the Suguden application activates the acceleration and proximity sensors.

(2) Using the proximity sensor, Suguden checks whether the phone is in a state away from the user's head or a surface. If a non-proximate state continues for longer than period B-1, the flow continues to decision (3). Since the phone can momentarily enter a non-proximate state due to user movements, we adjusted period B-1 so that such a case would not be judged to be a non-proximate state.

(3) Using the acceleration and prox-

imity sensors, Suguden checks whether the phone has been placed on a surface in a horizontal and faced-down state.

(3)–1: This step uses the acceleration sensor to check whether the phone is in a horizontal state.

Specifically, the method used here detects a horizontal state by using the absolute value of gravitational acceleration obtained from the acceleration sensor. If the gravitational acceleration of the *x*-axis and *y*-axis are each zero, the phone is considered to be in a horizontal state. However, in actual situations, the desk or table on which the phone is placed may not be strictly horizontal, so we established thresholds for angles θ_x and θ_y of the *x* and *y* axes (*x*-axis threshold B-2, *y*-axis threshold B-3) and use the absolute value of gravitational acceleration to check whether these angles are less than those thresholds (**Figure 7**).

(3)–2: This step uses the proximity sensor to check whether the phone is near an object. If the phone is in a proximate state, it is considered to be resting on a desk, table, or other kind of surface.

Finally, if the state that simultaneously satisfies the conditions in steps (3)–1 and (3)–2 continues for period B-4, the motion-detection conditions are satisfied. Otherwise, the detection flow starts again from step (3).

3.3 Shake-twice Motion (Disconnect/reject-call Operations)

In a disconnect operation, when the user moves the phone away from the ear and shakes it, the shaking position differs among users.

Furthermore, in a reject-call operation at the time of an incoming voice call, the user brings the phone up to the chest to check the identity of the caller, but the shaking position likewise differs among users.

For this reason, we designed the algorithm to detect whether the user has explicitly shaken the phone regardless of the phone's position or state at that time. We also incorporated control measures to prevent a reaction to oscillations that occur in normal use of a smartphone such as when walking.

The method used for detecting the shake-twice motion is shown in **Figure 8**.

(1) After recognizing an opportunity to initiate motion detection, the Suguden application activates the acceleration and proximity sensors.

(2) Suguden confirms that the phone has been stationary for period E-1 (has not exceeded threshold E-2) and begins decision (3). If E-2 is exceeded within E-1, decision (2) is repeated using the time at which E-2 was exceeded as the start point.

(3) Suguden confirms that the phone

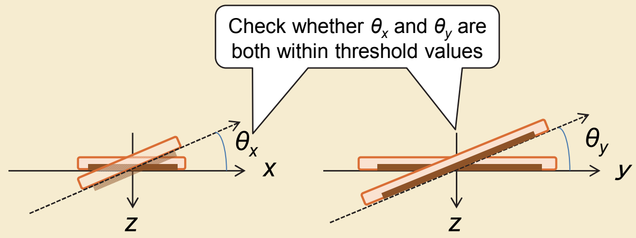

Figure 7 Horizontal state detection

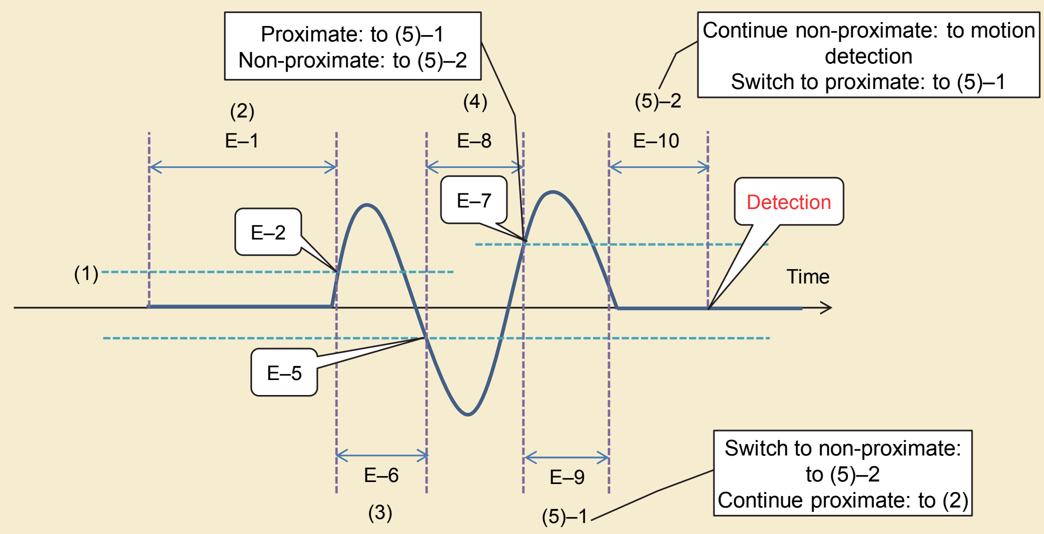

Figure 8 Shake-twice motion detection

has exceeded threshold E-5, the inverse of E-2, during period E-6 and begins decision (4). If acceleration exceeding E-5 is not detected within E-6, the flow returns to decision (2).

(4) Suguden confirms that the phone has exceeded threshold E-7, the inverse of E-5, during period E-8. If acceleration exceeding E-7 is not detected within E-8, the flow returns to decision (2).

Now, if the proximity sensor detects a proximate state at the point at which threshold E-7 is exceeded, the user may have performed an unintended operation such as holding the phone up to the ear, so a transition is made to decision (5)–1. However, if the proximity sensor detects a non-proximate state at the point at which threshold E-7 is exceeded, a transition is made to decision (5)–2.

(5)–1: If the proximity sensor switches to a non-proximate state during period E-9, a transition is made to decision (5)–2. If the proximity sensor continues in a non-proximate state for period E-9, Suguden decides that the user has performed an unintended operation and returns to decision (2).

(5)–2: If the proximity sensor continues in a non-proximate state for period E-10, Suguden detects that a shake-twice motion (disconnect/reject-call operations) has occurred. If the proximity sensor switches to a proximate state during period E-10, Suguden decides that the user has performed an unintended operation and makes a transition to decision (5)–1.

3.4 Move-phone Motion (Hide Caller's Name Operation)

Users have stated that there are times when they do not wish surrounding people to see the name of the caller of an incoming call when placing their phone on a table during a meeting. In response to this need, we have made it possible to disable display of the caller's name at the time of an incoming voice or video call and to then display the name by having the user intentionally pick up the phone or slide it back and forth on the table.

(1) After recognizing an opportunity to initiate motion detection, the Suguden application activates the acceleration sensor.

(2) Suguden obtains phone motion from the change in gravitational acceleration using the acceleration sensor.

The method used for detecting the move-phone motion is shown in **Figure 9**.

(2)–1: Get maximum and minimum values over a fixed period of time for gravitational acceleration in each of the *x*, *y*, and *z* directions.

(2)–2: Calculate difference *Δ* between those maximum and minimum values obtained for gravitational acceleration in each of the *x*, *y*, and *z* directions.

(2)–3: Using the total value of the absolute values of difference *Δ* as a criterion, determine that the phone has moved (motion detection) if that criterion is greater than a certain value and display the caller's name.

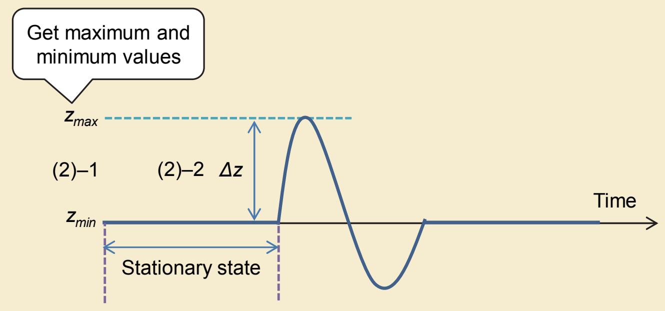

Figure 9 Detection of move-phone motion (for phone movement in the *z*-axis direction)

4. Conclusion

"Suguden" enables a user to operate a phone using natural actions like bringing the phone up to one's ear without having to perform tapping operations that have so far been the norm. Going forward, we will focus on many natural actions performed by users in daily life and incorporate a variety of them in Suguden. Our goal is to facilitate the further evolution and spread of Suguden functions so that they become a part of everyone's lifestyle. We also plan to add enhancements to the Suguden algorithm to further improve its accuracy.