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Slope Information Collection System Using Sensor Information from General-Purpose Wheelchair Users

Kenichi ARAI, Chisato MIURA, and Toru KOBAYASHI
Nagasaki University, Nagasaki, Japan
k.arai@cis.nagasaki-u.ac.jp

Abstract— **In this study, we propose a system that collects slope information from various types of sensors attached to general-purpose wheelchairs and feeds this slope information back to wheelchair users. General-purpose smartphones are attached to the wheelchairs in this system, and by collecting information from the various sensors embedded within the smartphone, slope information can be collected in a short period of time and with low cost. In this paper, we show the results of an evaluation experiment using this system.**

I. Introduction

Most obstacles for wheelchair users exist on the sidewalk. A typical obstacle is the slope. When there is a slope on the sidewalk, wheelchair users tend to feel anxiety when moving and avoid travelling on routes other than those to which they are accustomed. If it were possible, therefore, for wheelchair users to know in advance about the existence of a slope, they would feel more relaxed about going out, and this in turn would increase the desire of wheelchair users to leave the house. Yet there is the problem that grasping information on where slopes exist requires a large amount of time and labor costs. Additionally, although a barrier-free map for the use of wheelchair users in the various regions of Japan has been created, this was mainly created by administrative bodies and volunteers, and it is not possible for wheelchair users to acquire the necessary information without the cooperation of non-disabled people.

In this study, we propose a system that collects slope information from various types of sensors attached to general-purpose wheelchairs and feeds this slope information back to wheelchair users. With this system, an unidentified large number of wheelchair users become the information providers. General-purpose smartphones are attached to the wheelchairs in this system, and by collecting information from the various sensors embedded within the smartphone, slope information can be collected in a short period of time and with low cost. In this paper, we perform an evaluation experiment using this system to demonstrate its effectiveness.

II. RELATED WORK

There is a system in which a smartphone (iPhone) is attached to a wheelchair, slope information is acquired using a gyrosensor embedded within the smartphone, and the system feeds back this slope information to the wheelchair user [1]. However, as this system acquires slope information using only gyrosensors, with this method of acquisition there is a large margin of error based on the state of movement, and slope information may not be acquired correctly. With this system, we consider sensors other than the gyrosensor embedded within the smartphone, and propose a method for acquiring information with a low margin of error even when moving.

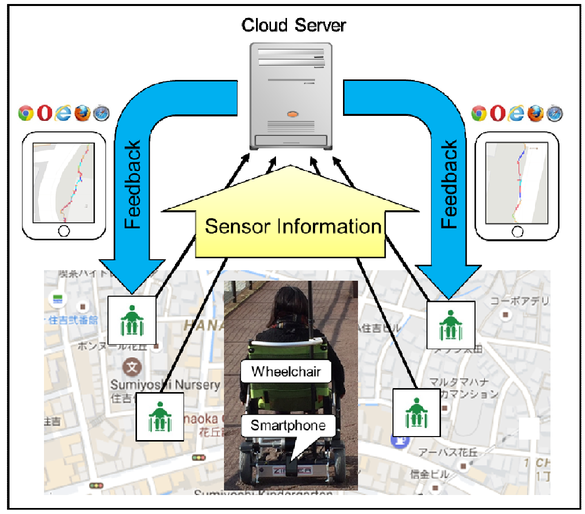

Fig. 1. Overview of slope information collection system

III. Slope information collection system

This system is comprised of a smartphone attached to a wheelchair and a cloud server (Fig.1). In the smartphone (FUJITSU Arrows M03, Android 6.0), there is an application installed for collecting and transferring the slope information. The wheelchair user, when going out, uses the application to collect slope information. The slope information is stored in the smartphone. After returning home, the wheelchair user uses the application to transfer the slope information stored in the smartphone to the cloud server. The cloud server (CentOS 7.3, Apache 2.4, PHP 7.0, PostgreSQL 9.3) stores the received slope information in a database, and publishes the slope information using a Web application. Users of the system can confirm the slope information using a public Web browser.

A. Collecting Slope Information

The smartphone application obtains slope information (information on slope angles and positions) from various sensors embedded within the smartphone. The slope information is acquired at 0.05 second intervals, and the mean value is calculated, using these values, every 1.0 seconds, storing the mean value as slope information on the smartphone every 1.0 seconds. The following two methods of calculating slope angles are implemented.

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- Method 1: Method of calculation using a gravity sensor.

$$\theta = \tan^{-1}\frac{GravityY}{\sqrt{GravityX^2 + GravityZ^2}} \cdot \frac{180}{3.14} \tag{1}$$

- Method 2: Method of calculation combining the use of a gyrosensor and triaxial acceleration sensor.

$$\theta(n+1) = \left(1 - 0.1 \cdot \frac{1}{1+(c-c\cdot a)^2}\right) \cdot \left(\theta(n) + \Delta\theta_g\right) + 0.1 \cdot \frac{1}{1+(c-c\cdot a)^2} \cdot \theta_a \tag{2}$$

In method 1, the slope angle is calculated using formula (1). In concrete terms, the slope angle is calculated by substituting the x axis, y axis, and z axis direction gravity acceleration acquired from the gravity sensor in formula (1).

In method 2, the slope angle is calculated using formula (2), i.e. using a complementary filter. Here, θ_g is the slope angle calculated from the gyrosensor. θ_a is the slope angle calculated from the triaxial acceleration sensor. c is a certain coefficient. a is the acceleration vector sum of each axis. Gyroscopic drift occurs when calculating the slope angles from the gyrosensor. This gyroscopic drift can be the cause of error. The complementary filter makes it possible to correct the error with the slope angle calculated from the triaxial acceleration sensor.

B. *Provision of Slope Information*

The cloud server provides slope information by displaying a color-coded mesh on Google Map using the Google Maps API, based on the slope information stored in the database. In this system, a virtual mesh is placed on Google Map with North latitude 50.389629° and East longitude 116.518321° as starting points, and a 3400km range on the East side and South in a shape covering Japan, delimited by 0.5m square rectangular spaces. The reason for placing a virtual mesh is to enable updating of the slope information in consideration of positional information (GPS sensor) error.

IV. EVALUATION EXPERIMENT

We performed evaluation experiments using this system to demonstrate its effectiveness. First, using methods 1 and 2 in section III.A, we conducted an experiment to assess the method with which we could acquire slope information with the smallest degree of error. This evaluation experiment was conducted in an ideal environment. In concrete terms, we placed a freely-adjustable stand on a cart at a slop angle of between 0-30°, and placed a smartphone on the stand, and conducted an experiment in which a cart was moved along a flat corridor surface. The experiment was performed with the two slope angles of 0° and 10°as the stand slope angles. Figure 2 shows the results of the experiment.

Average error is the average error of the data acquired during 200 seconds. With the experiment results, we learned that the method of calculating the slope angle in a moving state, i.e. the method of calculating using a gravity sensor is effective (average error 1.12°).

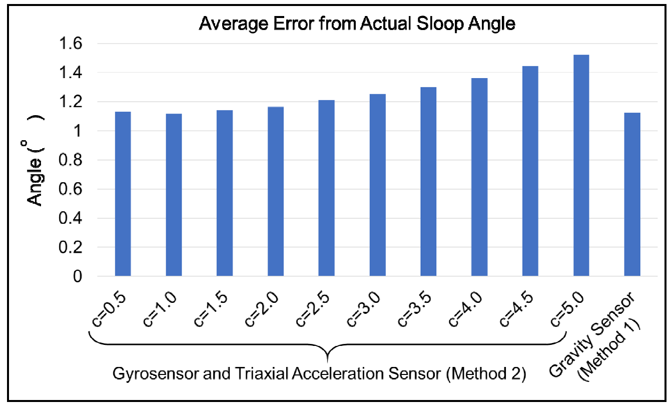

Fig. 2. Evaluation results in ideal environment

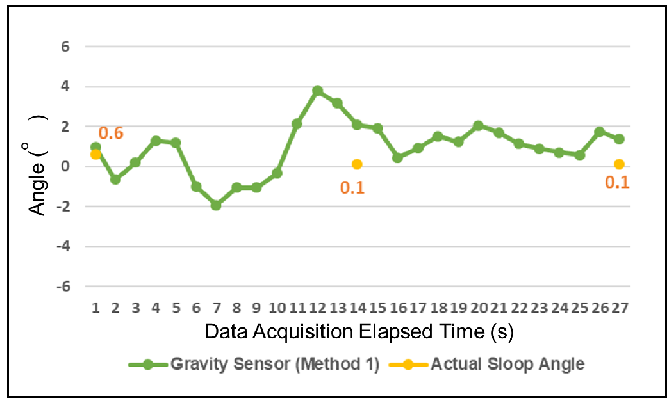

Fig. 3. Evaluation results in actual environment

Next, we conducted an experiment, as an evaluation experiment that envisages the actual environment, that involved moving along sidewalks around Bunkyo campus of Nagasaki University in Japan. The results of the experiment are shown in Figure 3.

The experiment results allow us to obverse that method 1 makes it possible to acquire the slope angle with low error compared to the actual slope angle on the sidewalk.

V. CONCLUSION

In this paper, we proposed a system to collect slope information from sensors attached to general-purpose wheelchairs and feed this slope information back to wheelchair users. Further, we conducted an evaluation experiment using this system. In the future, we plan to deploy this system as part of the system (Barrier-Free Street View System [2]) for wheelchair users that we are developing.

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