

## Design of Falling Context-aware System based on Notification Service using Location Information and Behavior Data

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### Abstract

*The majority of existing falling recognition techniques provide service by recognizing only that the falling occurred. However, it is important to recognize not only the occurrence of falling but also the situation before and after the falling, as well as the location of the falling. In this paper, we design and propose the falling notification service system to recognize and provide service. This system uses the acceleration sensor of the smartphone to recognize the occurrence of a falling and the situation before and after the falling. In order to check the location of falling, GPS sensor data is used in the Google Map API to map to the map. Also, a crosswalk map converted into grid-based coordinates based on the longitude and latitude of the crosswalk is stored, and the locations before and after falling are mapped. In order to reduce the connection speed and server overload for real-time data processing, fog computing and cloud computing are designed to be distributed processing.*

**Keywords:** Behavior Recognition, Falling, Fog Computing, Cloud Computing, Sensor, Google Maps

## 1. Introduction

WHO cited falling followed by a traffic accident as a main cause of death due to unintended accidents[1]. Many behavior recognition studies and falling recognition studies have been conducted to recognize these falling and to provide quick first aid. The most widely used method of recognition is to use several sensors[2, 9]. Most of these methods collect and process sensor data from the sensor, and then recognize the falling or not according to the threshold value[3]. In recent years, the penetration rate of smartphones has been greatly increased, and sensor data is collected and processed using sensors built-in smart phones[4].

However, the majority of these falling researches are only recognized of the fact that a user has been falling, and it is impossible to know what state the user is in due to falling. In addition, since the location

information is not provided, information on where the user has fallen cannot be obtained. Especially, in the case of a falling in the crosswalk, a falling accident can cause a traffic accident, so it is necessary to infer the falling situation accurately and quickly. This is because it is difficult to provide an accurate and appropriate service by simply recognizing falling. Therefore, it is necessary to recognize the behavior of the user and infer the situation and provide appropriate service [5-6]. In this paper, the situation is any type of information that classifies objects (people, places, etc.) that have interaction between the user and the system [7].

Falling Context-aware Technology for inferring falling and the resulting situation should collect and process sensor data in real time through various sensors. As data is collected and processed in real time, the amount of data increases exponentially, which leads to an increase in server latency and server overload [8]. To solve this problem, it is necessary to distribute data using fog computing and cloud computing.

In this paper, we provide a notification service by perceiving user's behavior and location using accelerometer and GPS sensor to recognize falling and infer the situation caused by falling. To provide this notification service, we propose the Falling Context-aware System based on Fog Computing and Cloud Computing. In addition, GPS sensor data is converted to grid-based coordinates to identify when a pedestrian falling.

The composition of this paper is as follows. In Section 2, we describe behavior recognition technology and cloud computing as related research. In Section 3, we describe the falling context-aware notification system proposed in this paper. Section 4 describes the scenario of the proposed system and falling situation's modeling. Section 5 describes the conclusions and suggestions of the proposed system.

## 2. Related Works

### 2.1 Behavior Recognition Technology

Behavior recognition technology is mainly used as a technology for health care by recognizing human behavior by using various sensors and understanding life pattern. Most of the researches on the recognition of the behavior are processing the sensor data collected by the acceleration sensor using the SVM(Signal Vector Magnitude) algorithm and classifying it according to the threshold value[3-4]. The SVM value can be obtained by the method of Eq. (1).  $Acc_x$ ,  $Acc_y$ ,  $Acc_z$  are values of the x, y, and z-axes of the acceleration sensor data, respectively.

$$SVM = \sqrt{Acc_x^2 + Acc_y^2 + Acc_z^2} \quad (1)$$

Also, SVM value obtained by Eq. (1) is divided by 1G and converted to 1G when it is still used. By defining preprocessing procedure and normalization order, white noise and calculation amount are reduced [10]. Human behavior can be broadly divided into static behavior and dynamic behavior[11]. Static behaviors include lying, sitting, standing and dynamic behaviors include walking, running and falling. These behaviors are not made up of individual behaviors, but rather are connected by various behaviors.

Based on the behavior state diagram, we can classify the user's situation according to pre-falling behavior and post-falling behavior[12]. In addition, falling situations that can occur during ADL(Activities of Daily Living) are as follows. The pre-falling states that can be used in this paper are "walking" and "running", and the states post-falling are "lying", "sitting", "standing", "walking", "running".

### 2.2 Fog Computing

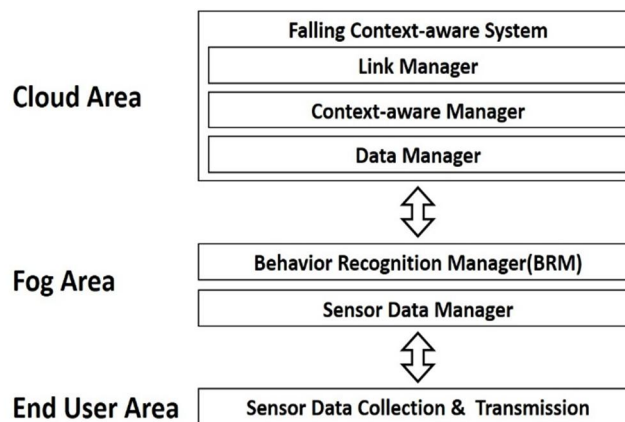
Fog Computing refers to a model that extends existing cloud computing services to the edge network area. Cloud computing is computing that provides services based on 'virtualized computing resources' using Internet technology [13]. In other words, it provides an environment that allows easy access to IT resources such as servers, which are services used in devices based on the Internet environment [14].

However, as processing, analysis, and storage of various and large amounts of data are performed only in a cloud server, an increase in connection latency and a server overload problem have occurred. Fog computing has been proposed as a solution to this problem. The basic theory of fog computing solves the server overload problem and the connection latency problem which are applied only to the cloud server by distributing the data gathering, processing, filtering, and analyzing in the fog computing between the end user and the cloud computing.

### 3. Design the Proposed System

#### 3.1 System Overview

In this paper, we propose the system to infer the user's falling situation using falling data and location data. In this system, recognize the behavior of the user by using the acceleration sensor. In addition, location data is the data where the falling occurred using the latitude and longitude data of the GPS sensor. We designed a distributed processing system using the fog server and the cloud server to efficiently process real-time sensor data and reduce server overload. Figure 1 shows the configuration of the proposed system.



**Figure 1. System Architecture**

This system is divided into the End User Area, Fog Area, and Cloud Area. The End User Area uses the acceleration sensor and the GPS sensor built in the smartphone to collect sensor data and transmit it to the Fog Area. The Fog Area was constructed using Raspberry Pi. When the sensor data is collected in the Fog Area, the sensor data is classified according to the metadata format and stored in the temporary storage. These data are processed and recognized by the BRM(Behavior Recognition Manager) to recognize behavior, including falling. When a falling occurs, falling data, pre-falling behavior, post-falling behavior, and GPS sensor data in Temporary Storage are transmitted to the Data Manager in the cloud area. In the cloud area, when falling data recognized in, mapping the behavior data and the user's current location through Link Manager and deducing it comprehensively infer the user's current situation. These data are stored

contiguously in the database in the cloud and helps to make more precise situation inference by referring to a similar situation in the future. In addition, the emergency center and the caregiver can be informed of the falling situation to enable quick first aid treatment.

### 3.2 System Flow

#### 3.2.1 Fog Area

In the system designed in this paper, the End User Area collects sensor data in real time and transmits it to the Fog Area. The sensor data is measured using the acceleration sensor and the GPS sensor built into the smartphone.

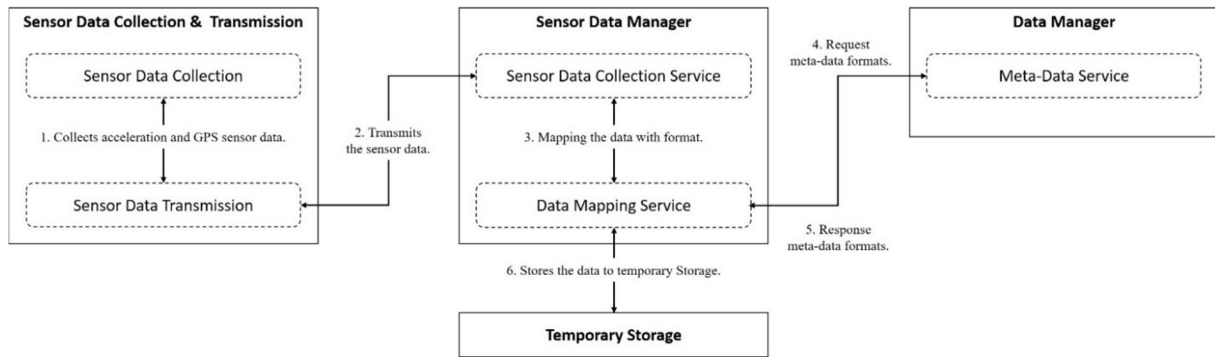


Figure 2. System Flowchart I

Figure 2 shows the process of collecting the sensor data in the End User Area and storing it in Temporary Storage. Collect acceleration data and GPS sensor data from the Sensor Data Collection. Transmits the collected sensor data to the Fog Area's Sensor Data Collection Service. In order to map the data, the Data Mapping Service requests the Meta-data format from the Data Manager of the Cloud Area. The data is mapped to the metadata format and stored in a Temporary Storage.

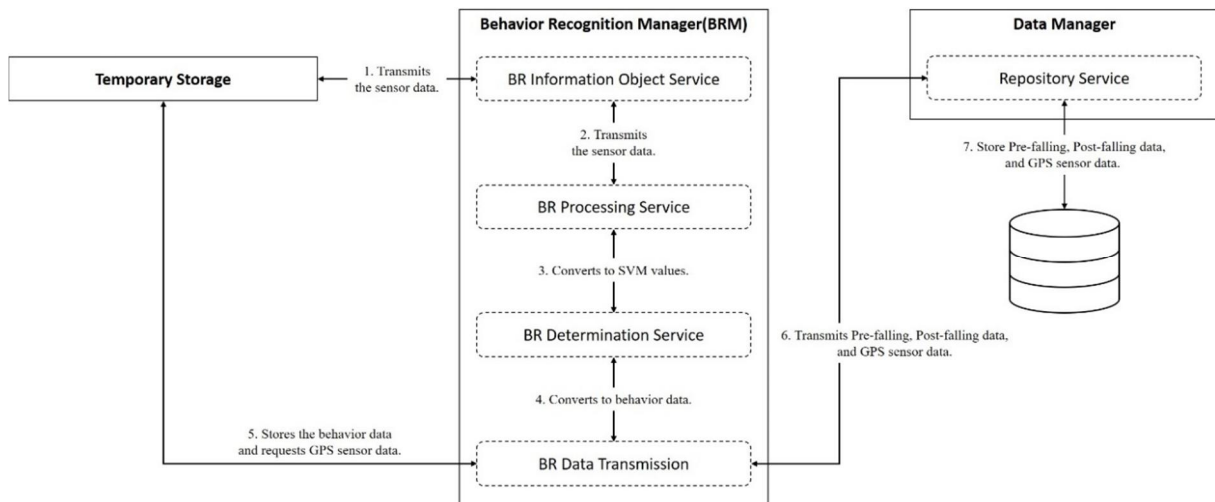
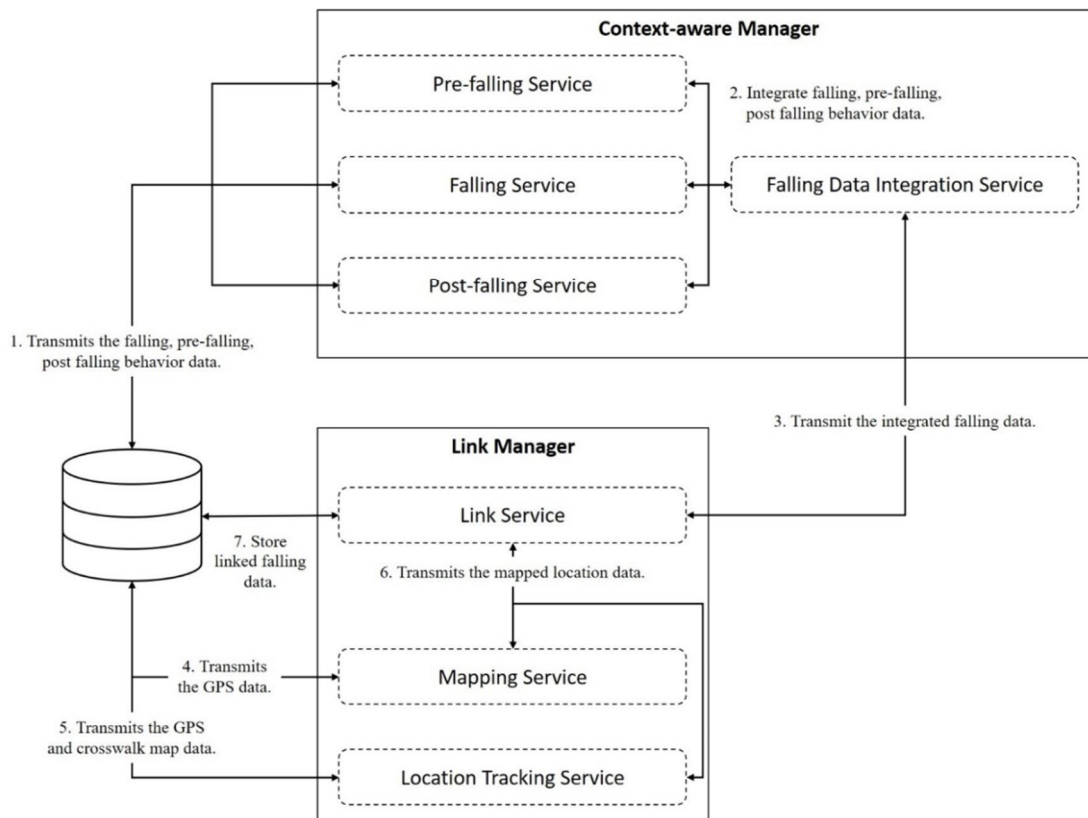


Figure 3. System Flowchart II

Figure 3 shows the process of storing data through Cloud's Data Manager when the Fog recognizes the

behavior and falling. Transmits the acceleration sensor data stored in the Temporary Storage to the BR Information Object Service of the BRM. BR Information Object Service classifies it according to the format and transmits it to BR Processing Service. BR Processing Service converts acceleration sensor data into SVM and transmits it to BR Determination Service. The BR Determination Service converts it into behavior data according to the converted SVM value and stores it to Temporary Storage through BR Data Transmission. In BR Data Transmission, when falling occurs, pre-falling behavior data, GPS sensor data, and falling data stored in Temporary Storage are transmitted to the Repository Service in the Data Manager of the Cloud Area. The Repository Service stores the received data in the database of the Cloud.

### 3.2.2 Cloud Area



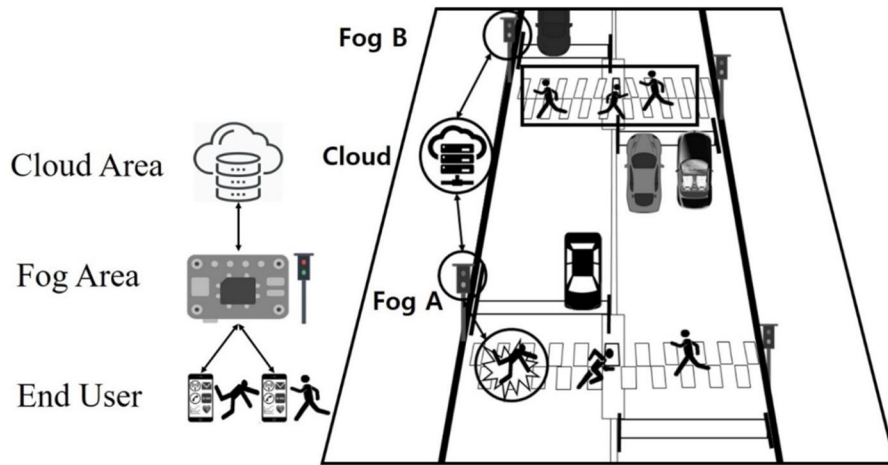
**Figure 4. System Flowchart III**

Figure 4 depicts the process of inferring falling situations in the Cloud's Falling Context-aware System. Behavior data stored in the Cloud database is transmitted to Pre-falling Service, Falling Service and Post-falling Service of Context-aware Manager. Based on this, it recognizes the pre-falling and post-falling behavior and transmits it to the Link Manager's Link Service. In addition, the database transmits the GPS sensor data to the Mapping Service and the Location Tracking Service, respectively. The Mapping Service uses the Google Map API to map and transmit it to the Link Service. The Location Tracking Service maps the crosswalk map and GPS sensor data and transmits it to the Link Service. Link Service links the data received from the Context-aware Manager, Mapping Service, and Location Tracking Service to the database, and provides notification service. The notification service transmits the map to the emergency center that maps the falling situation and the fall location based on behavior data pre-falling, post-falling behavior data.

## 4. Example of Proposed System

### 4.1 System Scenario

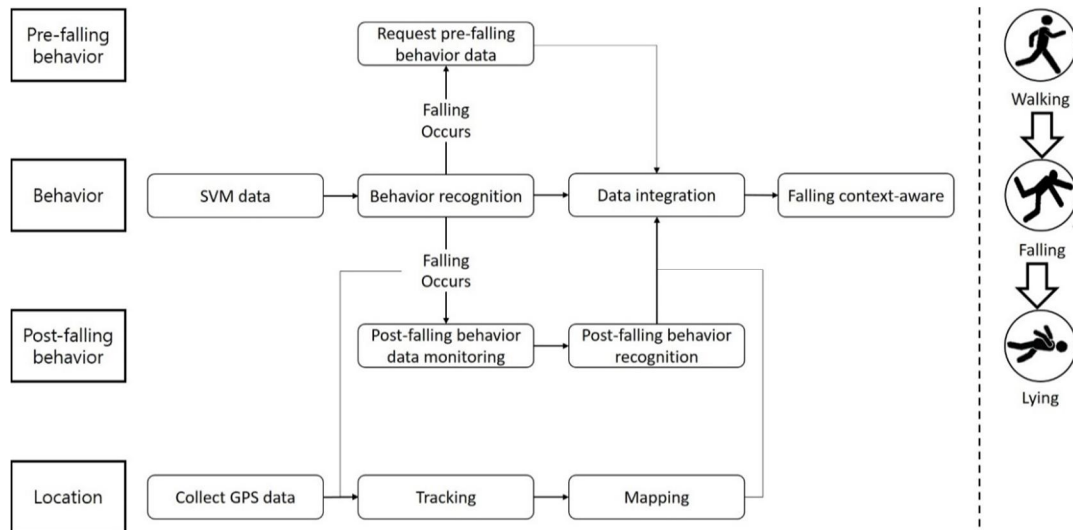
#### 4.1.1 Example of Applied System



**Figure 5. Example of Falling Context-aware System**

Figure 5 shows an example of applying the Falling Context-aware System proposed in this system when falling in the crosswalk. When falling occurs on the crosswalk, the user transmits the acceleration sensor and GPS sensor data of the smartphone to the Raspberry Pi in the Fog Area. Raspberry Pi was attached to each traffic light. When falling is recognized in the Raspberry Pi, it is transmitted to the Cloud server to infer the falling situation. In addition, use the Google Map API and crosswalk maps to map falling location.

#### 4.1.2 Falling Context-aware Method



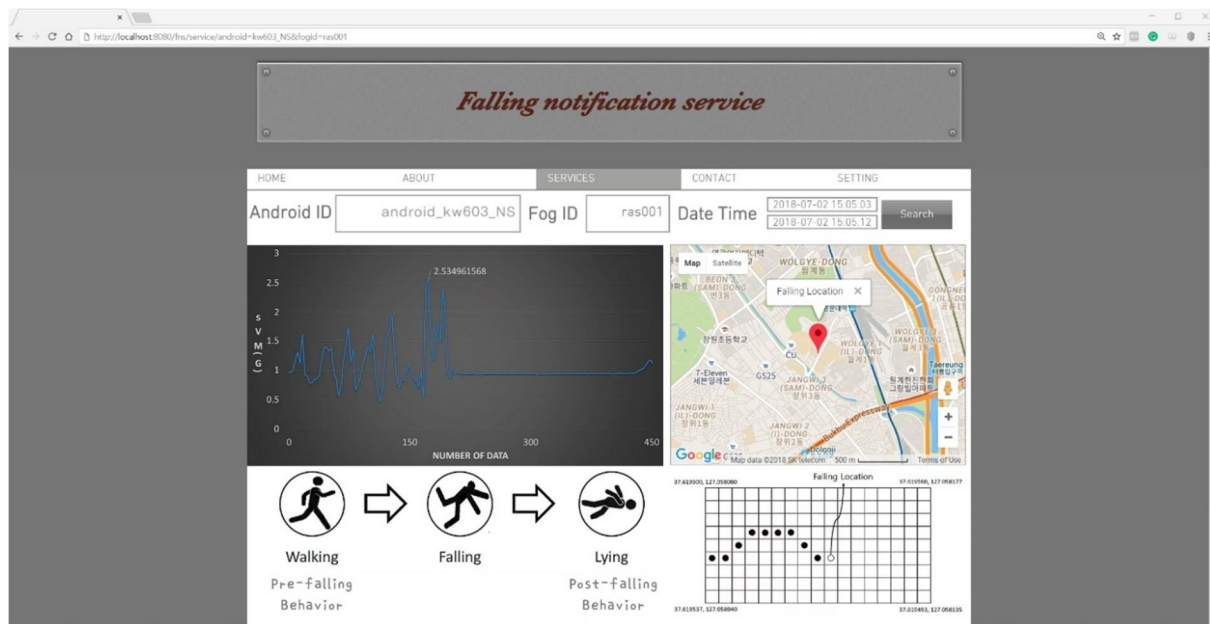
**Figure 6. Method of Falling Situation**

Figure 6 shows the situation before and after the falling based on the behavior state diagram when the falling occurs in the crosswalk[12]. Each behavior collects data from the acceleration sensor and converts the

data into SVM values, which are classified according to the threshold and standard deviation to recognize the behavior. The falling occurs within a short time of about 2 seconds. Therefore, in order to recognize the falling situation, the window was divided into 3 seconds, and the behavior before and after falling was compared. In the case of walking, running, and falling, there is a similar threshold value. Therefore, it is recognized that the threshold value is 2G or more, and then the state of 3 seconds is a static behavior, that is, 1G is a falling.

In addition to the behavior data, the falling location is also important to infer the falling situation. To do this, we collect data from the GPS sensor and display the falling location using the Google Map API. However, precise falling situations cannot be deduced by expressing information only on the sidewalks and roads. Therefore, it is divided into 1m units based on the GPS coordinates of each vertex of the crosswalk, and the location information of the crosswalk is converted into a grid type map and stored.

## 4.2 System Interface



**Figure 7. System Interface**

Figure 7 shows the proposed system's interface in this paper. Android ID, Fog ID, and time can be entered to check the falling location. On the screen, can see the SVM graph, the behavior before and after the falling, the map mapped using the Google Map API, and the path before the falling that maps to the crosswalk map.

## 5. Conclusion

In this paper, we propose the notification service based on falling situation. For this, we used real-time sensor data. In order to process this high-capacity sensor data in real time, we solved the problem of connection latency and server overload based on Fog Computing and Cloud Computing. In addition to the behavior data, we also map the falling location from the GPS sensor and construct a crosswalk map based on the lattice by dividing the falling location by 1m on the basis of the latitude and longitude of each vertex of the crosswalk.

In order to more precisely infer the falling situation, this system utilizes the location information in the previously proposed Falling Context-aware System. This will provide a notification service according to the falling situation, and contact the emergency center to induce quick first aid treatment.

However, since the error range of the GPS sensor of the smartphone which is generally used is 0 ~ 5m, in order to recognize the more accurate location information, falling recognition smartphone which can measure more precise sensor data is needed. In addition, we will introduce fuzzy logic to recognize the exact behavior of ambiguous SVM values and introduce deep learning to recognize various and precise behaviors. To smoothly provide notification services, Geofencing technology will be added to provide notification services directly to the vehicle if the vehicle is within a specific area of the crosswalk where the falling occurred.

## Acknowledgement

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