Design of Signal Delay System for Vulnerable Pedestrians Based on IoT

Sung Ho Sim

Abstract Background/Objectives: ***With the development of traffic systems, it is becoming possible to provide services considering pedestrian safety in providing services that reflect the functional requirements of traffic flow. It is developing into an intelligent system through linkage with IoT through the 4th Industrial Revolution. This flow provides situation-specific services to drivers and pedestrians to enable a safe traffic environment.***

Methods/Statistical analysis: ***The development of IoT has been increasing in various demands in the traffic environment for the safety of walking. The IoT environment-based traffic control system can provide mobility that guarantees pedestrian safety while providing smooth traffic flow. Walking zone monitoring using the IoT device can collect information about characteristics and situations that appear to pedestrians. Through the collected information, it is possible to provide a signal delay service that guarantees a safe walking time to the pedestrian.***

Findings: ***The existing traffic system calculated the walking time considering the traffic flow, the walking speed of the general public and the characteristics of the area. This is a consideration for vulnerable pedestrians, and it only provides a long signal time. This part guarantees safety in waiting time, but it cannot guarantee safe walking in case of signal interruption in the pedestrian zone. In this paper, IoT-based signal delay system was proposed to overcome the problem of existing pedestrian signals. IoT based signal delay system can guarantee the safety in the pedestrian zone by collecting vulnerable pedestrian information through monitoring the pedestrian zone and providing vulnerable pedestrians conditional signal delay service.***

Improvements/Applications: ***IoT-based signal delay system collects pedestrian zone information using existing traffic system and IoT device. It requests signal delay service based on the collected information analysis. Based on the requested service, the signal controller provides the signaling time to the pedestrian in the pedestrian zone with the appropriate signal delay.***

Keywords: ***IoT Environment,Signal Delay, Vulnerable Pedestrian, Traffic Flow, Walking Signal.***

I. INTRODUCTION

As vulnerable pedestrians (children, elderly people, people with disabilities, etc.) have increased their social participation needs and opportunities, securing of means of transportation and provision of traffic environment for the vulnerable pedestrians has become a social concern. As of 2013, domestic vulnerable pedestrians is about 25% of the total population, or, one in four. 48.9% of vulnerable pedestrians are elderly, followed by children, infants and toddlers, disabled persons and pregnant women [1,2]. The elderly population of Korea, which has entered the aging society, was 13.1% in 2015 and is expected to increase to 24.3% in 2030 [3]. The increase in the elderly population leads to an increase in vulnerable pedestrians. However, there is lack of basic research on vulnerable pedestrians and a lack of vulnerable pedestrians traffic services. Much research is under way to improve the traffic environment to ensure the mobility of vulnerable pedestrians. There are focuses on mobility support such as vulnerable pedestrian vehicle support service and provision of customized public transport for types of vulnerable pedestrians, but there are difficulties in practical application [4,5]. Also, the research on the walking environment of vulnerable pedestrians is insignificant. The demand for pedestrians is increasing due to the development of traffic environment. Although the conditions for pedestrians' rights and pedestrians to walk safely and conveniently are improving, the traffic system still considers only ordinary pedestrians, focusing on traffic flow. Traffic signal operation design is a minimum consideration for pedestrians according to vehicle - oriented signal design. In the case of vulnerable pedestrians, the walking time is terminated before the crosswalk pass is completed and is exposed to an accident risk [6]. In order to compensate for this, the speed of the vehicle is restricted to specific areas such as the child protection zone and the elderly protection zone, but it is not applied to the general crosswalk, and only partial effect can be obtained. In order to improve the walking time, a walking time estimation model was proposed based on vulnerable pedestrians. Additional time is provided for the pedestrian zone of the vulnerable pedestrians, but the vulnerable pedestrians are at risk for unexpected situations or signal cut-off in the pedestrian zone [7].

ICT technology provides new services in connection with various fields. IT-based technology is evolving from Intelligent Transportation System, which is applied to traffic environment, to Intelligent Cooperation System [8]. IoT can connect to wired / wireless network and provide various services through collaboration [9]. This can provide a variety of services through intelligent relationship building in which objects and objects or people and objects communicate and share information using networking and sensing [10,11]. This study proposes an IoT-based signal delay

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system where the vulnerable pedestrians can safely walk in the pedestrian zone while minimizing influence to traffic flow in order to improve walking environment of vulnerable pedestrians. This prevents pedestrians from being exposed to danger of the need for high transit time of the pedestrian zone or due to signal interruption in the pedestrian zone. For this purpose, the pedestrian zone can be monitored through the IoT device and the signal controller can be provided with the signal delay request based on the collected information.

II. RELATED WORK

2.1. *Pedestrian signal time calculation*

A signaling device refers to a device operated by a person or an electric power to indicate signals such as proceeding, stopping, turning, attention, etc. by means of letters, symbols or lights for road traffic. The signaling device provides the same benefits as increasing safety or improving communication because it assigns priority to alternate routes such as pedestrians or vehicles in an intersection or a single road and instructs or alerts to take a designated action. Pedestrian signal time is divided into pedestrian green signal and pedestrian flashing signal time. The pedestrian signal time of the pedestrian crossing should be considerably comfortable for many users to cross and it is necessary to secure enough time for pedestrians to cross. The pedestrian signal time is divided into [Green time + Green flashing time], and it is suggested that utmost care should be taken so that the pedestrians do not have any urgency due to green flashing. In the Traffic Safety Practice Manual, the minimum green time equation is presented as follows.

$$T = t + \frac{L}{V} \quad (1)$$

Here,

t : Pedestrian green signal time(Excluding flashing signal)

L : Pedestrian crossing distance(m)

V : Walking speed(m/s)

Pedestrian green signal time excluding flashing signal was uniformly 7 seconds, and pedestrian crossing distance was divided by walking speed to calculate the flashing time. The walking speed was generally 1.0 m/sec and school areas applied 0.9 m/sec [12].

2.2.Existing research methods for vulnerable pedestrians

There is guard zone designation and voice guidance signal installation for the vulnerable pedestrians. Since the signal time of these areas is calculated based on the average value, it does not fully reflect the characteristics of vulnerable pedestrians [13]. The pedestrian surveillance system detects and monitors moving vehicles and pedestrians for high-risk areas of traffic accidents. In this case, it cannot be detected when the vulnerable pedestrians move together with the pedestrian, and there is a problem about identification at night [14]. As a system for the elderly in the aging society, there is the Green Man Plus card system. This is a system where elderly people with a Green Man Plus card are provided with additional walking time by touching a card to a card terminal such as a pedestrian signal, which is somewhat lacking in coping with situations occurring in the pedestrian zone. The smart walk signal is composed of a Bluetooth signal recognition device, a traffic signal controller, a local server, and a central server to distinguish between general pedestrians and vulnerable pedestrians. The local server processes the traffic flow information of the traffic signal controller and alleviates traffic flow. Central server receives information of local server and performs system monitoring and management functions such as pedestrian signal. Smart pedestrian signal automatically recognizes vulnerable pedestrians to improve usability and provides additional walking time and acoustic signal guidance service. The smart walk signal ensures the adequacy of walking time but there is a weak part in the safety part of the vulnerable pedestrians when the signal is cut off in the pedestrian zone. Figure 1 below shows the structure of the smart pedestrian signal [15].

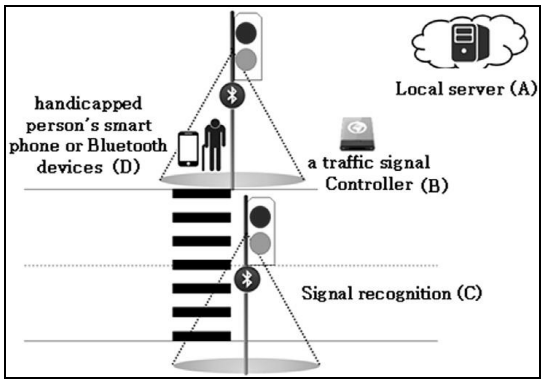

Figure 1. Smart Crosswalk Traffic Light Structure

III. PROPOSAL METHODS

The vulnerable pedestrians are often limited in access to traffic information and access to information. They are more restricted in their ability to actively respond to the traffic environment and rapidly changing transportation systems. In order to provide the traffic information service at the same level as the general public and to provide the traffic environment, the system design should be reflected in the type of service and time provided for the vulnerable pedestrians. Traffic environment support using IoT technology can provide services tailored for types and conditions of vulnerable pedestrians. This paper proposes IoT based signal delay system to provide secure mobility to the vulnerable pedestrians.

3.1. IoT based signal support system

The pedestrian signal time is basically divided by the walking speed, and the pedestrian safety is applied considering the number of pedestrians, density, and area characteristics. The signal time of the pedestrian is calculated considering the general pedestrians. Information on walking time is simply indicated by flashing green lights and pedestrian safety is not guaranteed after the pedestrian signal timeout. To solve these problems, an IoT-based signal support system that can provide a signal delay service is proposed. The signal delay service can guarantee the mobility of the vulnerable pedestrians by delaying the

signal flow to guarantee the safety of the pedestrian even after the pedestrian signal termination. Because the various characteristics and situations in vulnerable pedestrians are difficult to predict, IoT devices are used to constantly monitor the pedestrian zone. In a typical walking situation, the signal control system maintains the traffic signal system. When information on vulnerable pedestrians is collected, the IoT-based signal delay system requests the signal controller to delay the signal. It also provides information on walking service support and signal control room so that the situation of vulnerable pedestrians and traffic flow can be controlled. The IoT-based signal delay system is composed of a vulnerable pedestrian information collection module for collecting pedestrian zone information, vulnerable pedestrians decision module for determining a common pedestrian, and a vulnerable pedestrians signal support module for supporting a signal delay corresponding to the determined vulnerable pedestrians. Figure 2 shows the IoT-based signal delay system.

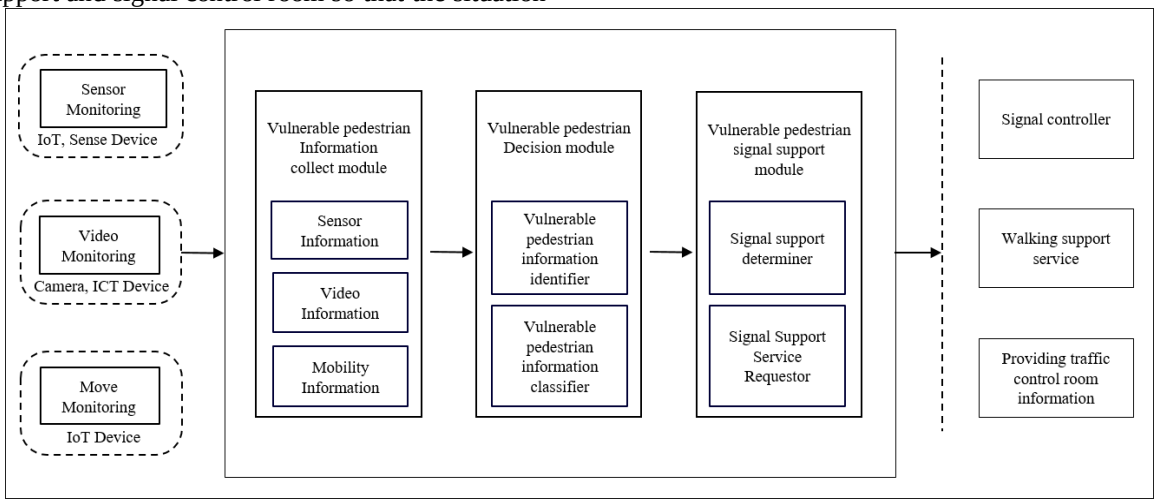

Figure 2. IoT based signal delay system

3.2. IoT signal delay system algorithm

IoT environment in the pedestrian zone is established to constantly collect information through device monitoring. Vulnerable pedestrian information collect module collect sensor information, image information and movement information. The collected information is used to identify and classify vulnerable pedestrian information in the Vulnerable pedestrian decision module. The classified information requests the signal support service through the signal support decision in the Vulnerable pedestrian signal support module. Figure 3 shows the IoT signal delay system algorithm.

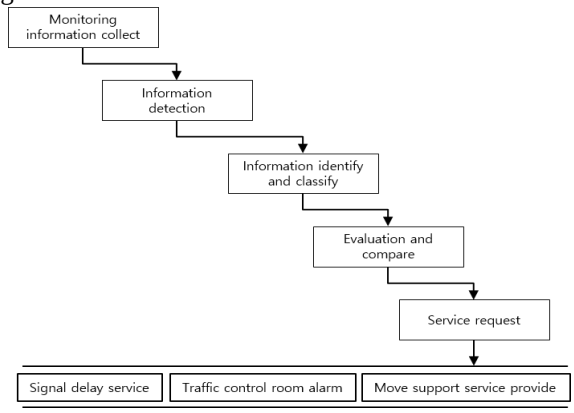

Figure3. IoT based signal delay system Algorithm

1. Collect information using IoT device monitoring collector
2. Detect vulnerable pedestrian information in pedestrian zone during pedestrian signal
3. When two or more pieces of information are identified in IoT device information from video information, sensing information, and movement information, classification is done using vulnerable pedestrian information class
4. If the classified information is included in the signal delay class, signal delay service is requested
5. Provide pedestrian signal time extension, situation control room alarm, mobile support service

3.3. Vulnerable pedestrian information collection method

The vulnerable pedestrian information collector collects information through monitoring devices connected to the IoT environment. It collects information generated from sensor device, camera, ICT device through monitoring and provides it to the vulnerable pedestrian decision module. Generally, the generated device information is stored in the database and only the information generated in the pedestrian zone is provided to minimize the delay time for identification and classification of information. The vulnerable pedestrians information collector consists of IoTinfoImporter, Information Module, and IoTinfoExporter. IoTinfoImporter collects IoT device monitoring information built in the pedestrian zone. It collects general data, sensing information, image information and movement information generated from IoT device and provides it to Information Module. The information module distinguishes the IoT device data provided by the monitoring from the information generated in the pedestrian zone, stores the IoT device data in the DB, and sends it to the IoTinfoExporter. In IoTinfoExporter, the defined information is divided into patterns of the provided information and stored in DB. Undefined information is provided by the vulnerable pedestrian decision module to identify vulnerable pedestrians. Figure 4 shows the vulnerable pedestrian

information collection.

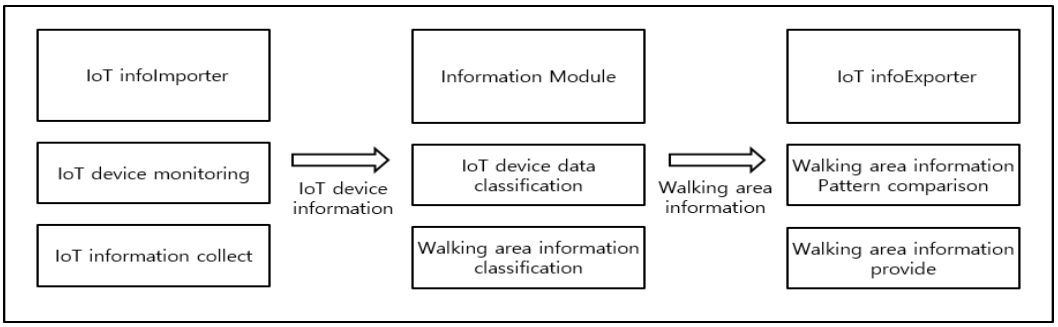

Figure4. Vulnerable pedestrian information collection Module

IV. COMPARISON ANALYSIS

The design of traffic system operation is focused on vehicle-oriented signal design with traffic flow. This traffic system provides only minimal pedestrian signal time without considering the importance of the walking environment. As the requirements of vulnerable pedestrians increase in the traffic environment, in order to solve these problems, the pedestrian signal time is limited to the designated area by simply estimating the walking speed slowly such as the elderly protection area and the child protection area. Pedestrian signal delays through simple zone design are not applied to the pedestrian zone on public roads and still cannot guarantee the safety of vulnerable pedestrians. The estimation of the pedestrian signal time using the characteristics of the pedestrian provides a time margin for the walking time, and it is possible to guarantee only the adequacy of the signal time without considering the situation occurring in the pedestrian zone. Smart pedestrian signals that incorporate IT technology identify IT devices of vulnerable pedestrians and control pedestrian signals. Based on the identified information, priority of signal wait for each vulnerable pedestrian type and selective additional walking time is provided. Smart pedestrian signals have also improved the walking environment by adjusting the signal priority and the pedestrian signal time per vulnerable pedestrians, but still cannot guarantee the safety of the pedestrian in the pedestrian zone. The existing traffic system attached importance to the functional part of the traffic flow and approached the traffic environment problem. These systems limit the mobility of vulnerable pedestrians and increase accidents with pedestrians. The pedestrian signal time was increased or walking islands were made to complement the walking environment, but they still do not guarantee stability in the pedestrian zone. Therefore, there is a need for research that can guarantee the safety of vulnerable pedestrians in pedestrian zone signal cut-off. In order to solve these problems, this paper proposed a system that can delay the pedestrian signal by using the IoT environment applicable to the existing signal system. The IoT based signal delay system monitors the pedestrian zone at all times by applying IoT device to the traffic signal system. Monitoring collects information from vulnerable pedestrians, classifies vulnerable pedestrians by type and provides context based signaling services. The safety of vulnerable pedestrians is guaranteed by extending the pedestrian signal time using the gait pattern and movement information in the pedestrian zone. The vulnerable pedestrian information collection module of the proposed system monitors the pedestrian zone. In the vulnerable pedestrian decision module, the collected information is used to determine the type of vulnerable pedestrians by using the movement information, situation information, and image information of the pedestrian. The vulnerable pedestrians signaling module uses the vulnerable pedestrians type information to determine the signal delay time and requests the signal controller to support the signal. In addition, it provides information on signal delay service to the request of the pedestrian support service and the traffic signal control room, thereby enabling a minimum traffic flow delay. The IoT-based signal delay system selectively delays the pedestrian signal time by applying the existing traffic system. Selective signal delays for vulnerable pedestrians can ensure safe walking without cut-off of pedestrian signals in the pedestrian zone. Table 1 shows the comparison and evaluation of existing studies on vulnerable pedestrians and proposed methods.

Table 1: Initial Set of features used for the experimentation

Search method / Comparisonitem	Study on walking zone designation	Study on walking time addition	Proposed method
Walking time extension	Not provided	Provided	Provided
Vulnerable pedestrian information acquisition	Not provided	Registered information	Real-time acquisition
Pedestrian monitoring	Not provided	Not provided	Provided
Signal extension point	Not provided	Pedestrian request	Pedestrian zone information

Pedestrian zone monitoring	Not provided	Not provided	Provided

V. CONCLUSION

In the change of traffic systems with the development of public transportation, the demand for pedestrian environment service is continuously increasing. In the driver-centered environment, which is centered on traffic flow, it is necessary to change the traffic environment considering vulnerable pedestrians. A number of studies have been conducted to improve the walking environment for vulnerable pedestrians such as the elderly, children, pregnant women and the disabled. Walking time is gradually being supplemented by research on vulnerable pedestrians. The environment for general vulnerable pedestrians has been improved by differently applying the pedestrian signal time estimation method based on the demand for vulnerable pedestrians by limiting the speed of the vehicle through the vulnerable pedestrian zone designation. Adjustment of pedestrian signal time in previous studies improved the mobility of vulnerable pedestrians, but the safety of the pedestrian zone is needed. The environment for vulnerable pedestrians still remains a problem when the signal is cut off in the pedestrian zone. This study proposed a system that can safely secure mobility of vulnerable pedestrians in the pedestrian zone and can be flexibly applied to traffic flows. Based on the information collected through monitoring based on the IoT environment, the study proposed a method to improve walking environment considering vulnerable pedestrians. It collects image information and situation information generated during walking and requests signal delay through vulnerable pedestrian classification, so it can provide delay time according to specific vulnerable pedestrians. Since it is possible to collect information on the irregular situation occurring in the pedestrian zone, it is possible to prevent the signal time cut-off in advance and to secure the stability of the pedestrian zone. The IoT-based signal delay system proposed in this study requests signal delay based on the information collected through monitoring the pedestrian zone. A signal delay service is provided based on the vulnerable pedestrian information collected through monitoring, so that a minimum delay in traffic flow is possible. Regular collection of information is stored in the traffic environment DB, and if vulnerable pedestrians are present and the situation in the pedestrian zone occurs, the signal delay system requests signal support services according to the vulnerable pedestrian classification. Also, by requesting walking support service and providing the generated information to the traffic situation control room, smooth walking support and traffic flow can be provided. In future research, an extended study will be conducted including calculation of compensation time for delayed traffic signal time.

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