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Evaluation of a Smart Traffic Light System with an IOT-based Connective Mechanism

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Abstract

Handicapped and weak pedestrians reportedly comprised 25.2% of the overall population of Korea in 2014. Most of the existing traffic light mechanisms are vehicle-oriented traffic control systems. However, pedestrian-oriented traffic systems are required to enable these pedestrians to safely walk across streets. Consequently, we propose a smart traffic light system that utilizes an IOT-based connective mechanism, which is incorporated into the actuated control algorithm of existing intelligent traffic systems. The proposed approach uses real-time vehicle information to facilitate optimal traffic flow, which enables weak pedestrians to cross streets safely and minimizes traffic jams. This smart traffic light system provides additional walk time only for weak pedestrians through signals received from their IOT devices. The results of three scenarios compared fixed time, actuated control, and smart traffic light walk signal to verify the efficacy of our proposed approach.

Key Words: Smart Traffic Light System, Smart Traffic Network System Simulations.

1. Introduction

In Korea, handicapped and weak pedestrians reportedly comprised approximately 25.2% of the overall population in 2014 [1]. These pedestrians walk across streets more slowly than normal pedestrians. It is difficult for them to safely walk across streets at traffic light signals at the basic walking speed (1 m/s). Currently, some regions have designated senior-protected and children-protected areas for weak pedestrians to increase the walk time allocated (walking speed: 0.8 m/s) [2]. However, three major problems have been identified with this approach. First, the increase in the allowed street crossing time can result in an increase in traffic jams. Second, 0.8 m/s (the standard walking speed of weak pedestrians) cannot cover every weak pedestrian. Third, in protected areas, it also provides additional walk time to normal pedestrians. Therefore, there is a limit to the amount of protection weak pedestrians can be given within protected areas. Owing to these problems, increasing the allowed walk time at traffic lights is difficult. Nowadays, many cities, including Seoul in Korea, are faced with increased traffic jams resulting from a rapid increase in the number of vehicles on their roads and lack of optimized traffic light signal algorithms. In general, most traffic light systems simply change their signals at a fixed time, regardless of the flow of vehicles.

Studies have been conducted with proposals incorporating technologies such as fuzzy logic [3], and multi-agent systems [4] in an effort to control and improve traffic light systems and thereby optimize traffic flow. However, these studies focus on how to adjust the timing of the traffic lights. Thus, their focus is primarily on vehicular traffic. However, it is necessary to consider weak pedestrian traffic based on pedestrian-oriented traffic lights. Consequently, we propose a smart traffic light walk signal approach that incorporates IOT devices with the actuated control algorithm of existing intelligent traffic light systems. Our proposed mechanism provides additional walk time only to help weak pedestrians walk across the street and minimizes the amount of time vehicles have to wait. Further, in emergency scenarios, it automatically manages the traffic lights at crossroads for safe and rapid movement of ambulances. In order to provide weak pedestrians with additional walk time, a receiver at the traffic light distinguishes Bluetooth signals transmitted from the IOT devices of the pedestrians and provides a customized walk time for them. In addition, with the IOT device, it recognizes signals from emergency vehicles (such as fire engines and ambulances) through detectors installed on the road, and manipulates the signal of the traffic light with a predefined value for emergency vehicles to move without delay.

In this study, the SUMO (Simulation of Urban Mobility) simulator was used to verify the efficacy of our proposed smart traffic light walk signal system. SUMO simulator is currently used for traffic simulation in various studies. In our study, we simulated three traffic light control scenarios: fixed time, actuated control, and our smart traffic light walk system incorporated with actuated control. Two of these traffic light scenarios are currently being used in several regions. Assuming two situations (normal condition and reduced speed owing to weather conditions) in the simulations, we compared the average time of all vehicles per change in vehicle congestion status in each situation.

The remainder of this paper is organized as follows. Section 2 reviews relevant studies. Section 3 outlines how the pedestrian-oriented traffic light system for weak pedestrians is modeled, and the algorithm of the traffic light system. Section 4 demonstrates each of the three traffic light system scenarios: fixed time, actuated control, and our smart traffic light walk system with actuated control. Section 5 presents the simulation results obtained. Finally, Section 6 concludes and outlines our plans for further study.

2. Related work

In this study, we used the SUMO simulator, developed by Behrisch et al. [7], for virtual simulation of the smart traffic light walk system. Jeong et al. [5] proposed a system that dynamically manages the traffic flow on the road in real-time from various devices. The proposed system is composed of three layers. The lower layer collects physical layer traffic information. The middle layer controls traffic flow operation. The upper layer enables the road traffic to dynamically flow based on intercommunication between the intersections. Park et al. [6] studied the pedestrian signal system. They found that although the safety of pedestrians is ensured by increasing the pedestrian signal period, an inevitable increase in traffic occurs. In their research, they minimized the increase in the signal time for pedestrians, and proposed a new pedestrian walk time for the safety of pedestrians. Behrisch et al. [7] developed and expanded the SUMO open source-based traffic simulation package. They state that it may be possible to conduct various studies about the route choice of vehicles, traffic light algorithm, and vehicle communication simulation using the package.

3. Pedestrian-oriented smart traffic light system

3.1 Smart traffic light walk system model focusing on handicapped and weak pedestrians

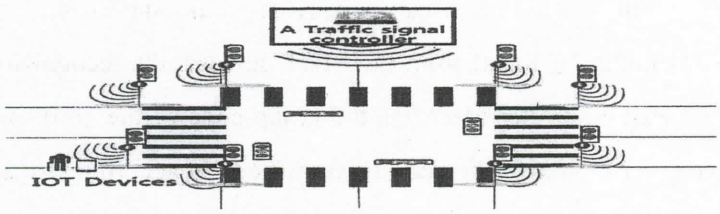

Fig. 1. Smart traffic light walk signal system model

Figure 1 shows our pedestrian-oriented smart traffic light walk system. This system can be divided into user, traffic light walk signal, traffic light, signal controller, and a central server that integrates and manages all of these components. The additional walk time is set as T+ (L/V), where T is the walk start time, L is the length of the crosswalk, and V is the pedestrian's speed,1.

Group code	Priority of pedestrians	V (m/s)
1	Blind	0.50
2	Elderly	0.57
3	Children	0.63
4	Temporarily handicapped persons	0.80

Table 1. Pedestrian group codes, priority levels, and average speed

Table 1 shows the §priority levels of various groups of pedestrians. We provide weak pedestrians with additional walk time using the following three steps:

Step 1: Install the exclusive mobile app on the smart device of the weak pedestrian and assign a group code between one and four. Step 2: Recognize the signal of the pedestrians waiting for the stop signal using the signal recognition device installed in the traffic light walk system. Step 3: Identify the pedestrian's group code from the detected signal. Compare the priority of the distinguished group code, and provide weak pedestrians with additional walk time based on priority.

Currently, the walking speed of general pedestrians is assumed to be 1.0 m/s. In protected areas, this walking speed is reduced to 0.8 m/s. However, when the average walking speed of children and seniors were actually calculated, they were found to be 0.63 m/s and 0.57 m/s, respectively [2].

The smart traffic light walk mechanism recognizes weak pedestrians such as the blind, seniors, children, and temporarily weak pedestrians and provides each group with a customized walk time.

3.2 Smart pedestrian traffic light system algorithms

Algorithm 1 is the procedure used to provide additional walk time to handicapped pedestrians by detecting the signal from their IOT devices. On recognizing their IOT device signal, a traffic signal controller identifies the group code of the corresponding IOT device, and sets the green (walk) time of the pedestrian traffic light according to the recognized signal. The green time includes the additional time required for these pedestrians. This is given as T+ (L/V), where T is start time, length L is a fixed value, and V is applied in consideration of the average walking time (m/s) of handicapped pedestrians.

Algorithm 1. Handicapped pedestrian recognition procedure

T: walk start time, L: length of crosswalk, V: pedestrian's speed

Input: group code 1–4 , Output: set the green time of the pedestrian traffic light

if there signals are being received from a handicapped pedestrian's IOT device

then check the group code number

    if the group code number is four **then**

      set the green time of the pedestrian traffic light T+ (L/V) // the additional walk time

    else

      if the group code number is three **then**

      set the green time of the pedestrian traffic light T+ (L/V)

      else

       if the group code number is two **then**

---

set the green time of the pedestrian traffic light T+ (L/V)
else
if the group code number is one **then**
set the green time of the pedestrian traffic light T + (L/V)
else
set the green time of the pedestrian traffic light T + (L/V)

Algorithm 2 outlines the movement process of cases 1, 2, 3, and 4 in Figure 8. In case 1, pedestrians and vehicles move in the directions E->W and W->E. At this time, the green time of the traffic light on the E, W lines is decided based on the green time of the traffic light walk signal because the traffic light walk system can detect the handicapped pedestrians and increase the walk time. In case 2, vehicles on the E, W lines go left. At this time, the green time is operated in the same manner as the actuated control based on real-time vehicle information.

Algorithm 2. Vehicle recognition

Input: vehicle , Output: traffic light signal

1: **case 1**

Decide on a green (walk) time using Algorithm 1

2: **case 2**

if a vehicle exists at node_e1, node_w1 **then**

decide green time = $G_{min} = 4_{(sec)} + [2_{(sec)} \times (L/20)] > G_{max}$(Max Green Time) ...... An Applied Technology and Traffic Analysis Program

3: **case 3**

Decide on a green (walk) time using Algorithm 1

4: **case 4**

if a vehicle exists at node_n2, node_s2 **then**

decide a green time = $G_{min} = 4_{(sec)} + [2_{(sec)} \times (L/20)] > G_{max}$(Max Green Time) ...... An Applied Technology and Traffic Analysis Program

4. Evaluated scenarios

Each scenario 1-3 was evaluated. The following policy was applied equally to all scenarios:

The crosswalk length of the general one-way two-lane road was 8 m. According to the Korea walk signal system, the walk time is about 15 sec: walk entry time (7 sec) + (length of crosswalk (8 m) / walk speed (1 m/s)). The walking speed of a senior in a protected area is 0.8 m/s, which gives a walk time of 17 sec. According to the road traffic law enforcement regulation, when the weather is normal, the highest speed of a one-way two-lane road is about 60 km. Conversely, when the weather is bad such as snowfall, rainstorm, or fog, this results in the visible distance being within 100 m, and necessitates that driver's drive at one-half of the highest speed.

4.1 Scenario 1: Normal traffic light system with fixed time

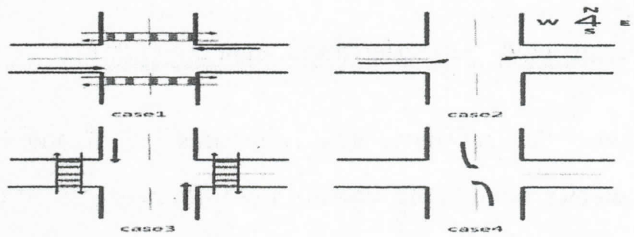

Fig. 4.Traffic system with fixed time scenario

This is the most general traffic light system. The traffic light operates in a predefined order of a fixed time period. Figure 4 shows one scenario situated with a fixed time.

4.2 Scenario 2. : Intelligent traffic light system with actuated control

The timing of a traffic light with an actuated control algorithm can be changed in accordance with various traffic situations.

Figure 5 shows the sensor node installed on the road. It detects the vehicles, and provides the optimal green time according to the vehicular flow at this sensor node.

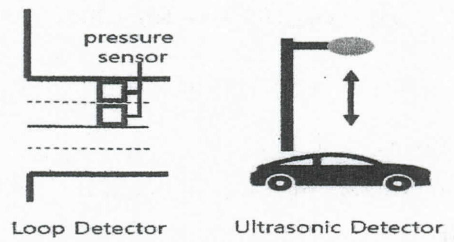

Fig. 5. Sensor node Fig.

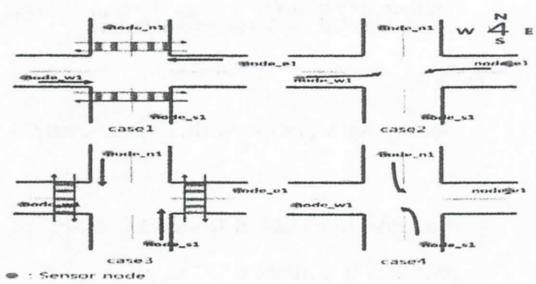

Fig. 6. Traffic system with actuated control

4.3 Scenario 3: Smart traffic light system on IOT-based connective mechanism

In this simulation, we applied a 25% probability on the basis of the handicapped and weak pedestrian's statistics from 2014. We implemented our proposed smart traffic light walk mechanism based on the actuated control. This sensor node was installed in the traffic light walk system to recognize signals from IOT devices in order to discern the handicapped and weak pedestrians. When it discerned such pedestrians it would provide them with additional walk time according to the predefined traffic time algorithm.

In cases 1 and 3, G_{min} of the traffic light signal does not change according to the vehicle flow, but is instead based on the green time of the walk traffic light in Figure 7.

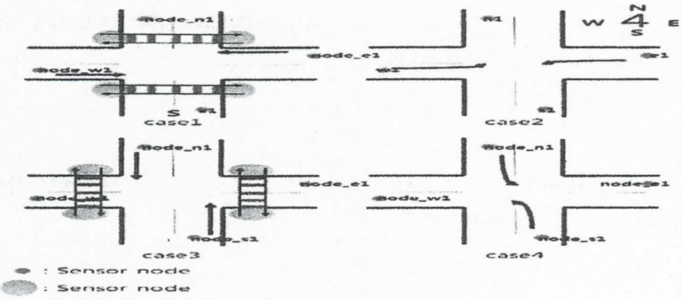

Fig. 7. Actuated control-based smart walk traffic light

In cases 2 and 4, the optimal green time equivalent to the actuated control traffic light is applied according to the flow of vehicles

5. Simulation

5.1 SUMO simulation.

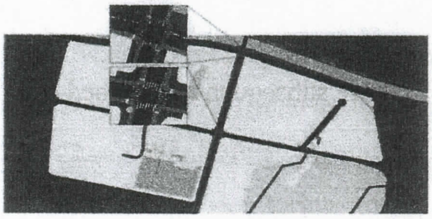

Fig. 8. Map used in the simulation

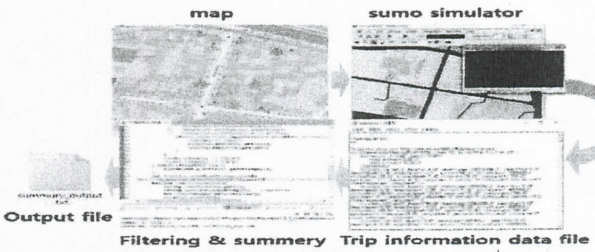

Fig. 9. Sample simulation process

We used the SUMO simulator to simulate the three scenarios. Figure 8 shows the map used in the simulations. This map shows two crossroads in the vicinity of Berlin city.

Figure 9 shows the simulation process. First, the map used in the simulation was selected. It was generated to work in the SUMO simulator. Detailed information was then set in order of vehicle, speed, and traffic light in the predefined file before starting the traffic simulation.

The SUMO simulator provides various pieces of data on the simulation results. We created a trip information data file in order to identify the changes in the average duration of all vehicles.

The created file contained information on thousands of vehicles. Using our developed JAVA program, we extracted the relevant information, and inserted it into the output file

5.2 Simulation results

Figure 10 shows the simulation results obtained for normal weather conditions. A steep slope can be seen as the number of vehicles increases from 200 to 300. The 300 vehicles occur as follows for the three scenarios: fixed time: 1639 sec, actuated control: 1263 s, and smart pedestrian traffic light: 1403 s. We also increased the average driving duration of the vehicles.

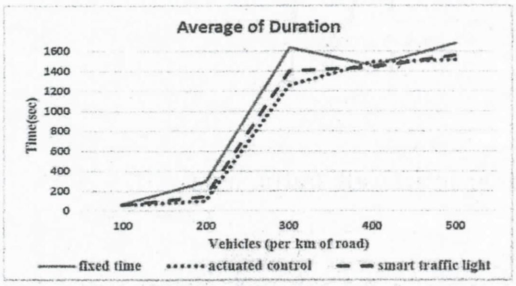

Fig. 10. Simulation results for normal weather conditions

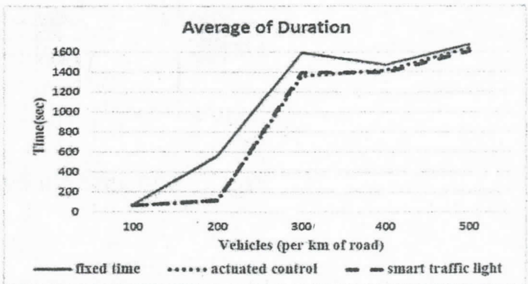

Fig. 11. Simulation results for abnormal weather conditions

Figure 11 shows the simulation results obtained for abnormal weather conditions. When the visible distance is within 100 m, the road surface is frozen, or more than 20 ml of snow accumulates, drivers must drive at one-half of the highest speed according to the road traffic law enforcement regulation.

On assuming the above situation, we set the highest road speed as 30 km/h instead of the original speed 60 km/h. The results depicted in Figure 11 were subsequently obtained

6. Conclusions

The number of vehicles on roads is increasing every year, and so is the number of handicapped and weak pedestrians. In conventional traffic light walk systems, these pedestrians experience difficulty walking across the crosswalk within the limited time allocated. Although increasing the walk time allocated would help to alleviate this problem, such a move can result in increased traffic jam incidences.

In this paper, we proposed a smart traffic light walk mechanism that incorporates IOT devices and an actuated control algorithm system based on real-time vehicle information. This traffic light system includes both a walk signal for handicapped pedestrians and an emergency algorithm with real-time vehicle information.

To verify the efficacy of our proposed system, we simulated three scenarios: fixed time, actuated control, and smart traffic light walk signal using the SUMO simulator to extract the average driving duration. The results obtained indicate that the proposed smart traffic light walk system results in an average increase of 4% in the duration of vehicles compared with the actuated control algorithm. However, we can guarantee that pedestrians can safely cross the street by providing additional walk time. We will develop a more enhanced smart traffic light walk algorithm and verify the efficacy of this model in future work.

7. Acknowledgments

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