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Design of Path Prediction Smart Street Lighting System on the Internet of Things

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Abstract

In this paper, we propose a system for controlling the brightness of street lights by predicting pedestrian paths, identifying the position of pedestrians with motion sensing sensors and obtaining motion vectors based on past walking directions, then predicting pedestrian paths through the route prediction smart street lighting system. In addition, by using motion vector data, the pre-treatment process using linear interpolation method and the fuzzy system and neural network system were designed in parallel structure to increase efficiency and the rough set was used to correct errors. It is expected that the system proposed in this paper will be effective in securing the safety of pedestrians and reducing light pollution and energy by predicting the path of pedestrians in the detection of movement of pedestrians and in conjunction with smart street lightings.

Keywords: Fuzzy System, Motion Sensor, Neural Network System, Path Prediction System, Smart City, Smart Street Lighting

1. Introduction

Due to various social and economic issues such as the development of urbanization, population growth, environmental issues, and economic growth logic, interest in smart cities has been increased and national investment has been made accordingly. Especially, smart street lightings are one of the most deployed facilities in outdoor space and are used as the most significant public facilities for constructing smart cities by extracting necessary data through various sensors.

Smart street lightings refer to a two-way wireless lighting control system based on artificial intelligence with the Internet and smart sensors. It allows for minimized dependence on managers, sharing information among systems and provision of appropriate lighting environments according to time and place.

Smart street lightings are currently used to detect moving persons or objects using LED street lightings rather than traditional sodium street lightings, and can also be used to control the brightness of the lights, thereby effectively reducing power and serving as realistic street lightings[1]. In addition, smart streetlights are being used in various Internet of Things environments by attaching sensors that measure vehicles, weather, traffic, and air pollution.

However, since these smart street lightings operate only when a pedestrian is detected in an attached sensor, they do not identify the path of the pedestrian in advance, unlike the existing street lighting environment where all street lightings are always on. Therefore, smart street lightings need to not only predict pathways of pedestrians based on previous movements but also saving power consumption while fulfilling functions of existing street lightings effectively.

Accordingly, this paper would propose a path prediction smart street lighting system to adjust brightness of the lights depending on pedestrians' routes. In other words, the system detects the location of pedestrians and finds out motion vectors based on previous walking. Then, it predicts pedestrians' pathways and regulates brightness of the lights.

This paper is composed as follows. Chapter 2 shows the proposed system configuration and design, and Chapter 3 shows the implementation results and perfor-

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mance evaluation of the proposed system. Finally, Chapter 4 presents conclusions and future research directions.

2. System Configuration and Design

The path prediction smart street lighting system, which this paper proposes, consists of IoT sensor lighting controllers, gateways, supervisory servers and path prediction systems.

IoT sensor lighting controllers are designed to be interworked with a lighting controller and LED (DALI, 1-10V, etc.) street lighting dimmable SMPS (Switched mode power supply) and to be communicated in two-way direction by using gateway and Mesh ZigBee.

The configuration diagram of the system proposed in this paper is shown in Figure 1.

Major standards for short-range wireless communications include Wi-Fi, Bluetooth, and ZigBee. Wi-Fi is centered on wireless Internet and file transfers based on Access Point, while Bluetooth is centered on connecting personal network devices centered on mobile phones. ZigBee, on the other hand, is a standard that focuses on the object communication and wireless sensor networks.

ZigBee is in charge of radio control of LED lighting and serves to reduce electrical usage by connecting with lights, lights-out, dimming and sensors. ZigBee is specialized in control and monitoring among the standards of short-range wireless communication and has been actively used in current control devices due to its large number of controllable nodes.

In addition, ZigBee communication is suitable to be applied to a streetlight control and monitoring system

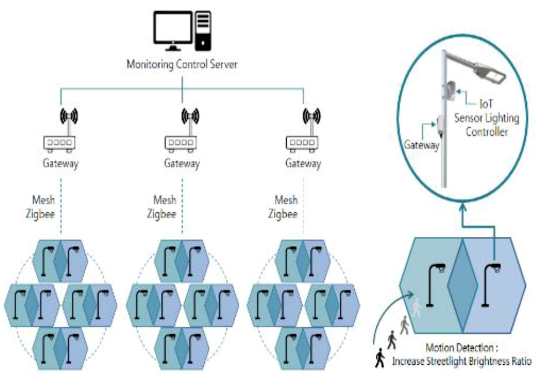

Fig. 1. The system configuration diagram.

because there is no installation cost and communication cost.

In general, the distance of street lightings is 20 to 40 meters, and ZigBee is a low speed communication method with communication distance of 100 meters, so it is suitable to control the street lighting system as ZigBee's communication distance. And since signals to control street lightings do not require a high transmission rate, 250 kbps low-speed communication is available, and ZigBee communication with low transmission rate is also small enough to build control systems with batteries or small power supplies.

ZigBee's network configuration consists of three structures: Star, Tree, and Mesh, although the Star structure is generally used a lot, it is currently using the Tree structure with the focus of LED lighting control and sensor network application. Although this is the most convenient method for Mesh architecture, it is not widely used because it is difficult to implement, it is expected that it will be the most popular method if network technology is developed[2].

The most important factor in networks of street lighting is Redundant Path. There are a lot of various obstacles for communications on the roads. These obstacles make communication difficult and unstable, and as a way to overcome them, in this paper, a network in the form of Mesh has been constructed[3].

It also enabled the Internet of Things messaging by linking external Internet networks with Mesh ZigBee networks using a Public/Subscribe pattern based on the Advanced Message Queuing Protocol (AMQP) protocol, a protocol of the Internet of Things[4].

By using mesh ZigBee network to link street lights to network, a bypass route is created through self-healing function even if there is a problem with the established communication path. In addition, since the adjacent nodes are hopped and visited the coordinator, it is possible to stably configure the network up to several kilometers.

ZigBee supports two modes: Transparent Mode (AT) and Application Programming Interface (API). In AT mode, the data itself can be sent and received, and simple transmission and reception are possible, but data cannot be sent and received dynamically between nodes.

However, API mode is a packet transmission method that is faster and more diverse than AT mode, and has more flexibility and reliability of communication method. API mode also allows dynamic communication between nodes by packetizing arrival addresses, packet form, signal strength, checksum and data when transferring data.

In this paper, API mode was used to construct mesh ZigBee network. In order to use energy efficiently when sending and receiving data from a mesh ZigBee network, there is a way to adjust the transceivers most efficiently or to reduce unnecessary network traffic. Also, there is a power management method of the node depending on whether or not it is used. In general, the mesh ZigBee network routing method has a lot to do with the Ad hoc routing method.

Typically, routing protocols include Ad hoc On-demand Distance Vector (AODV) and Dynamic Source Routing (DSR). These methods have overhead in the sense of transmitting data and have disadvantages in terms of energy consumption because routing information is stored in tables. Also, the disadvantage of using control messages for routing is that packets get larger in size[5].

In this paper, the Source Routing method was used to solve these problems. The routing information of the AODV routing method is stored in the routing table, while the Source Routing method includes the routing information in the network frame itself of the data[6].

For gateways, about 200 lighting controllers are configured as a single set, which is controlled and controlled by the monitoring control server. The street lightings with motion sensing sensors carry measurement information to the gateway and the measured information is sent to the monitoring and control server via CDMA communication.

A supervisory server finds locations of pedestrian based on measured information. Then, it orders gateway to increase brightness of lights when there is a pedestrian and to decrease the brightness when there is no pedestrian. Gateway adjusts the brightness of street lightings within its range of control by commands of supervisory server.

In addition, in this paper, the path prediction system was proposed. The path prediction system is applied to the smart street lighting system using soft hand-off characteristics for motion sensor detection range and walk tracking[7,8]. That is, as soft hand-off is employed to anticipate location of the next base station based on information about former base stations, pedestrian's next route is expected with reference to information about previously passed street lightings.

The detection ranges of motion sensors on street lightings are overlapped to track down a person's movements and their directions. If the pedestrian is detected in motion sensing sensor, the system finds out walking tracking vectors. Divide this into hours to obtain motion vectors and predict the most recent motion vectors as the next predicted path [9]. Since the average walking speed of a person is 4 km/h, motion vectors are obtained at 1 second intervals, assuming a speed of approximately 1 m/s.

In this paper, the rough set for preprocessing process, fuzzy system, neural network system, and error correction model were used to enhance the performance of path prediction smart street lighting system in the proposed the Internet of Things environment using data obtained through motion vector as shown in Fig. 2[10].

Data preprocessing methods include Moving Average (MA), Integrated Moving Average (IMA), and Linear Interpolation. The preprocessing process in this paper was preprocessed by linear interpolation.

Creates an appropriate number of differential data with nonlinear time series data characteristics and minimizes any imperfect elements that may occur in designing the system model if the characteristics of the generated differential data can well represent the characteristics of the circular data. Therefore, the linear interpolation presented to expect the learning effect of insufficient data was overcome and accurate prediction

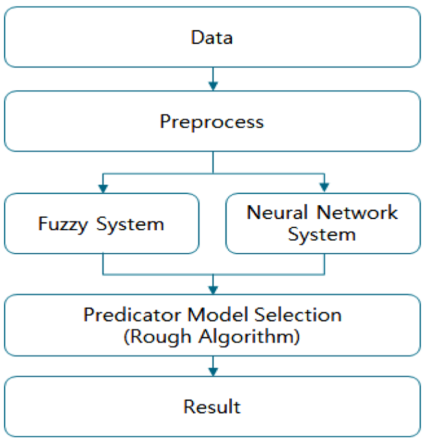

Fig. 2. The path prediction system configuration diagram.

was made possible by processing the data

In general, the performance of the prediction system shows a close relationship to the learning data used for the design of the system. In the case of highly fluctuating data such as predictive data, many learning data may contain a significant amount of inconsistent and unnecessary information, and in the case of too little learning data, the system may not contain the information required.

Also, prediction was more accurate by processing data, the prediction system was designed in parallel structure of fuzzy system and neuronal system. The prediction of fuzzy system for general pattern was quite accurate. However, the accuracy of prediction on data showing rapidly increasing or decreasing patterns dropped. On the other hand, prediction of neuronal system for general patterns was less precise than that of fuzzy system. However, its prediction for data showing rapid inclement or decline was more accurate than that of fuzzy system[11,12]. Thus, in order to use both advantages of the system, this paper has designed a system of parallel structure. The rough set is utilized to select error correction model based on the results of both systems[13].

The model selection of the prediction system is a necessary structure to utilize both the advantages of the fuzzy system and the advantages of the neural network system. Therefore, to select a better predictive system model when the error correction of an arbitrary value will demonstrate the proposed system by presenting a final error correction result.

The proposed system has two result values predicted through the fuzzy and neural network system in the internal output results. In general, the final output to the output of multiple forecasting systems is the simplest method: using the output from the forecast system with the best performance in the training process, using the output means of multiple forecasting systems, and taking weighted averages based on performance[14,15].

In this paper, using the theory of the rough set, a method was used to select and drive the forecasting system to carry out the prediction according to the properties of input data. It also simplified the processing of the system by reducing properties and eliminating unnecessary rules by analyzing the result value data of both systems so that they can select the system to be used according to the resulting value.

3. System Implementation and Performance Evaluation

In this paper, data were sampled to 64 data lengths to assess the performance of the proposed forecasting system, 54 of which were used for system design and the remaining 10 for system performance evaluation.

Finally, both Root Mean Square Error (RMSE) and Minor Relative Error (MRE) are used as index for evaluating system performance and can be obtained using the following Eq. (1) and (2).

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(y_i - \hat{y}_i)^2} \quad (1)$$

$$MRE = \frac{1}{N}\sum_{i=1}^{N}\frac{|y_i - \hat{y}_i|}{|y_i|} \times 100\% \quad (2)$$

Table 1 shows the results of a performance evaluation of the path prediction system. It can be seen that the performance of the relatively neural network system is superior to that of the fuzzy system in all the index values. However, the final prediction performed by the system selection process indicated that some characteristics of the fuzzy system were involved in the final prediction and that the performance of the proposed system was improved, and that the predictive system was highly capable.

In addition, the RMSE index showed that the performance of the neural network system was better than that of the fuzzy system, but the MRE index showed that the performance of the fuzzy system was better than that of the neural network system. It can be seen that these index values have been properly reflected, and that all indicators of the final predictive performance of the system proposed in this paper have improved considerably.

It was therefore possible to confirm that the proposed design process for the proposed system could be considered as a reasonable indication, as shown by the results in Table 1, in particular, that predictive errors could be compensated through the system selection process. Also, it can be seen that the lack of information or the lack of data that can occur when designing a prediction system can be overcome by linear interpolation.

Fig. 3 is the result of implementing the path prediction smart street lighting system in the Internet of Things environment proposed in this paper. (a) represents 20 per cent of the brightness of a street lighting

Table 1. Performance evaluation of the system

	Learning Section		Evaluation Section		
	Fuzzy System	Neural Network System	Fuzzy System	Neural Network System	Proposed System
RMSE	36.671	32.383	26.461	18.395	17.936
MRE(%)			0.312	0.214	0.202

(a) No motion Detection (Brightness : 20%)

(b) Motion Detection (Brightness : 100%)

Fig. 3. The smart street lighting system implementation.

when no pedestrian is detected; (b) represents 100 per cent of the brightness of a street lighting when a pedestrian is detected.

4. Conclusions

The existing smart street lighting system failed to provide customized services for pedestrians only because it did not predict the path of pedestrians by adjusting the brightness value of the street lightings when they were detected by sensors attached to the street lightings.

In this paper, we propose a system for controlling the brightness of street lightings by predicting the path of pedestrians using motion vectors of data measured through motion sensing sensors.

In addition, by using motion vector data, the preprocessing process using linear interpolation method and the fuzzy system and neural network system were designed in parallel structure to increase efficiency and the rough set was used to correct errors.

It is expected that the system proposed in this paper will be effective in securing the safety of pedestrians and reducing light pollution and energy by predicting the path of pedestrians in the detection of movement of pedestrians and in conjunction with smart street lightings.

Further studies are intended to predict paths through mathematical modeling or pattern analysis of motion vectors for more accurate path prediction. Also, more effective systems would be developed by using analysis of the amount of the electricity used over periods and by analyzing data about road users (cars, bicycles and pedestrians) detected by smart sensors such as the extent of traffic congestion and walking patterns.

Acknowledgments

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