Poster Abstract: Exploring effectiveness of a predictive light control mechanism for wireless sensor networks

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ABSTRACT

Light management for buildings or streets is important for safety, security and comfort. However, it is not economical to keep the lights on in places without people. Although there is a lighting system with power-saving feature that lights up automatically when it detects moving objects, it has a problem that it does not light up unless the objects approach the immediate vicinity of the lights. In this work, we aim to realize the system that collects motion detection data of objects using a wireless sensor network, predicts the approach of a person from a position farther than before, and appropriately controls lighting on / off. In this system, data is exchanged between neighboring nodes, and each node autonomously judges lighting control. We discussed a predictive control method and made experiments for an adequacy confirmation. First, we constructed a system to verify the predictive control method and made a data acquisition experiment using PIR motion sensors. Next, we examined methods for a movement prediction and lighting control based on the acquired data, and confirmed that control results provide sufficient utility.

CCS CONCEPTS

•Networks~Network services~Programmable networks;
•Computer systems organization~Embedded and cyber-physical systems~Sensor networks

KEYWORDS

Wireless Sensor Networks, Light Control, Prediction Mechanism, Distributed Processing, Cooperative Processing

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1 Introduction

It is known that lighting accounts for a significant proportion of power consumption in buildings[1]. By reducing the time spent illuminating an unoccupied space, the wasteful power consumption of lighting can be significantly reduced. On the other hand, if there are people but the lights are not turned on properly, the comfort of the user will be impaired[2]. The purpose of this study is to construct a lighting control system that achieves both power saving and user comfort. This paper mainly describes the results of studies on the method and implementation of predictive control of lighting. First, in order to verify the predictive control method, we conducted an experiment of sensing data acquisition, and examined the method of motion prediction and lighting control based on the result of the experiment.

2 Predictive lighting control model

In the proposed system, lighting is controlled based on the movement of a person detected by using a PIR motion sensor. It has the following three types of control methods depending on the difference in the length of time from the time detected by the sensor to the time when the actual control is performed.

Real-time control: When the sensor detects a person approach, it immediately turns on the associated light.

Predictive control: From the sensing results of multiple adjacent nodes, the movement of people in the near future is predicted, and the lights are turned on and off in advance.

Schedule generation from history: It predicts the periodic movement of people using the past sensing history and generates a lighting control schedule.

This paper focuses on the discussion of predictive control, which is the second control method. A node obtains sensor information of itself and surrounding nodes through cooperative actions, and predicts person movement based on that information.

In this study, the main controlled areas are corridors with branches, which will be modeled as a graph structure. We assume that there are multiple nodes in a two-dimensional space and that persons can move between adjacent nodes. This graph structure can be regarded as superposition of several one-dimensional space. Therefore, we first consider a movement prediction method in an one-dimensional space. Consider the case where nodes $x_0, x_1, x_2, \dots$ are arranged in this order on a straight line. Here, we consider the control of x_0

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lighting. If an object is moving from x_2 to x_1 , it is highly likely that it will move to x_0 next, so turn on the light of x_0 .

When this is extended to a graph structure, there will be multiple adjacent nodes when viewed from x_0 . This corresponds to the existence of multiple models of one-dimensional space as seen from x_0 . Therefore, basically, it is possible to realize the prediction at x_0 by superimposing the required number of models in one-dimensional space.

3 Experiments for predictive control

The purpose of this work is mainly to control lighting in corridors such as offices. Since it is assumed that an unspecified number of people are walking in such a place for the purpose of movement, it is considered that it is very difficult and unnecessary to identify an individual and control the lighting according to the person. In the proposed system, we do not aim to identify each person, but a sufficiently natural lighting control result can be obtained from the perspective of each person.

Figure 1: Experiment environment.

In the experiment, one person walks from the start point to the end point in Fig.1 for about 10 seconds. During this time, the three nodes constantly sense at 1-second intervals. The result was sent to the host PC.

In order to examine the procedure for predictive control, we first created a program that predicts the sensing results of node 3 using the sensing results of node 1 and node 2 in Fig.1. In this program, when it is detected at node 2, it makes a prediction by collating it with the detection time at the past nodes 1. The result is shown in Fig.2. Each point on node 4 means the prediction results of node 3.

Figure 2: Results of the prediction based on linear approximation.

If the difference between the detection time at node 1 and the detection time at node 2 is extremely long or short, it will be played from the result as a false detection or an impossible prediction. The cases of less than 2 seconds and the cases of 8 seconds or more are excluded from the prediction results. It means making a prediction using only data that falls within the expected movement speed range. There is a possibility that persons move extremely fast, such as by running, but in such cases, real-time control described in the previous section shall be used.

By referring to the actual detection time at node 3, it was found that all the data was included in the prediction result. The prediction is delayed compared to the actual detection time. This is because there was a set of data that could be interpreted as walking at a moving speed slower than the moving speed at the time of the experiment when the actually detected data were combined. As a result, a control result can be obtained in which the lighting period of the lighting is extended. However, in the actual lighting control, the lighting period is extended because it is required to turn off the lights after for a while when a person passes a certain point. Thus, it is not considered a critical issue.

From the viewpoint of power consumption and processing speed, it is considered that communication intervals should be as long as possible. Next, in order to investigate how much the communication interval should be increased to hinder the prediction, a similar experiment was conducted by doubling the walking speed with the parameters unchanged (Fig.3 (a)). As a result, it was concluded that the arrival may be predicted later than the actual detection time, and that a sensing interval similar to that of the first experiment is practically required. We also conducted an experiment with two walking persons and found that there was no problem if the walking speed was the same (Fig.3 (b)).

Figure 3: Results of other experiments.

Unlike the tracking system, our system is not intended for individual identification of moving objects. The purpose of the system is not to make strict predictions, but to obtain sufficient results from a point of view of user comfort, power saving in the entire building with a small sensing data size.

4 Conclusion

In this paper, we examined a concrete method of predictive control of lighting in a lighting control system using a wireless sensor network. The goal of the proposed system is to realize not only power saving but also comfort for users by introducing this control method. The method was examined based on the acquired data, and the lighting control behavior based on the prediction result was further examined. As a result, it was confirmed that sufficiently useful lighting control could be realized. Currently, an implementation of the proposed method as a real-time and distributed algorithm on a sensor network system is ongoing.

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