Light Control and Path Prediction

Using Human Detection

A Report for the

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Ethan Belculfine

Adeeb Alqahtani

Abdulrahman Aljurbua

Department of Computer Science and Engineering

California State University San Bernardino

Abstract: The focus of this project is to create a low-cost, energy-efficient alternative to current methods of reducing energy consumption of street lamps. Current methods involving limiting the use of street lamps, and in some cases not using them at all. As an alternative, we present a method of energy usage reduction that relies on inexpensive sensors and a small controller. This method will ensure that lights are only used when they are needed, which is when people are around them. This method reduces energy consumption without compromising safety. Our system has three primary light settings: No light, low light, and high light. The system determines what setting to use based on the presence of atmospheric light and the presence of humans, primarily. Additional factors, such as the presence of fog, and additional settings, such as the fog light setting, are used to provide the user with more effective light control. In addition to simple human detection, this system can perform basic estimations of a person's position, speed, and direction on a linear field. This functionality relies on the same hardware as the simple human detection, and can perform estimations with reasonable accuracy. These estimations are used to provide users with more effective light control in the way that it can light a user's path shortly before the user has arrived at any point in the path. This estimation technology is useful for long pathways, such as those found in tunnels or across bridges. The basic human detection functionality is useful for virtually any street lamp or similar light administration application.

I. Project Overview

This project is a low-cost, energy-efficient, and highly modular detection-based light system with basic path prediction functionality. The system uses an Arduino controller, any combination of a variety of different detection sensors, and environmental sensors to perform its functions. There is a growing need for energy efficiency and automation in all areas of our lives. Currently, street lamps that illuminate urban areas try to cut back on energy consumption by simply turning off for long periods of time.This creates a number of safety issues, which defeats the purpose of the street lamps altogether. A system that can run on low amount of energy and with cheap hardware, to keep initial cost of buying system down and cost of energy consumption down, would help cut back on the cost of operating street lamps without creating safety issues. Safety issues stem from peoples' lack of awareness of their surroundings, due to a lack of light. This lack of awareness increases the likelihood that a person will encounter wildlife, criminals, and drivers who are unaware of their presence. This human detection based system could potentially increase the security of its covering area with the use of path prediction technology, while increasing the energy efficiency of a wide-area grid of street lamps. By lighting a path in front of a target, people in the surrounding area would become more aware of the system's target, which increases the security of the area. By keeping the system low-cost, local governments and businesses will be more likely to invest in the system, which would keep safety issues from arising or persisting. The modularity of the system will keep costs down by allowing users to use whatever components are best for a particular use, and the detection-based functionality will keep energy consumption down to reasonable levels by keeping the system from being active when no one is around to use it.

The final version of the system is reasonably modular, although it is not as modular as it could be. Support for more types of sensors could be included to improve the modularity of the overall system. The system uses two 110 Volt AC sockets, and could potentially use one if correct adapters and circuitry are used. Further, the final implementation of path detection is not as accurate as it could be, due to underdeveloped noise control. Noise control was only partially implemented, due to the project's time constraint. Even with the final implementation of the project's limitations, the system is able to detect nearby humans and make basic estimations of their location with reasonable accuracy.

II. Project Goals and Objectives

The primary goal of this project is to create a robust and modular system that can use virtually any human detection sensor to provide light for nearby people. The system should also be able to detect certain environmental conditions and respond accordingly, to ensure proper function and energy efficiency. To keep the cost of implementation down, the system should be able to use a variety of different human detection sensors for its path prediction functionality. Path prediction functionality should include the ability to predict the speed and direction of a target on a linear path. Keeping this functionality to a linear path eliminates the need for additional hardware, which keeps the cost of the overall system down and increases its appeal to potential users. To effectively use this path prediction information without significant changes to the surrounding infrastructure, this system should be able to use wireless transceivers and receivers. The system should be able to detect atmospheric light levels of the surrounding area, which will ensure the system is only used when it is needed.

III. Project Devices

The system uses a number of human-detection sensors, object-detection sensors, environmental condition sensors, wireless transceivers and receivers, power relays, and external circuitry, as well as a controller. The controller used is an Arduino MEGA board, with the Arduino language (a variant of C++) as its programming language. Any Arduino board with an adequate amount of input and output pins can be used as a controller, due to the robust nature of the Arduino language and software. For each single package, any combination of two detection sensors are used. Detection sensors include object-detection sensors such as ultrasonic range sensors, or human-detection sensors such as PIR motion sensors. The system is able to use any detection sensor that has a boolean output, and has support for the HC-SR04 Ultrasonic Sensor. Environmental sensors used in this project include an atmospheric light sensor, the Phantom YoYo Arduino compatible Mini Luminance Light Sensor, to detect atmospheric light levels, and a humidity sensor, the DHT11 Temperature & Humidity Sensor Module, to detect fog. The wireless communication components used for this project are the RF 433MHz Transceiver and Receiver, although any transceiver and receiver supported by the Arduino VirtualWire library could be used. An Arduino-supported power relay, the SMKAN 8 Channel DC 12V Relay Module for Arduino, is used to power external lights.

External lights are made up of basic wires, sockets, 40W light bulbs, an LED strip, and a 110V AC power plug.

To support communication between hardware components and the Arduino controller, basic Arduino-supported components such as wires, LED’s, solderless breadboards, and USB power cables are used. In the case that a USB outlet cannot be used to power the controller, a 110V AC to USB power adapter is included.

IV. Project Design and Methods

All source code is contained within the master file, which uses the Arduino language. The code runs on an Arduino MEGA board, although it could run on any Arduino board with an adequate amount of input and output pins.

The source code relies on four external libraries - TimedAction, Utility, VirtualWire, and DHT. The TimedAction library is used to implement time-based protothreading on the Arduino. This allows the board to perform all required functions concurrently, without having to neglect or significantly delay necessary functions. This functionality is necessary to allow the accompanying wireless receiver to receive and process messages from many different nodes, in addition to its other functions. The Utility library is only used to provide the ‘foreach’ loop functionality. The VirtualWire library is used for data transmission and reception, as well as data packaging for transmission and package interpretation. The DHT library is used to interpret data from the humidity sensor, which includes humidity and temperature.

The system has four primary procedures, with one supporting procedure. The four primary procedures include a signal transmit function, an environment check, a signal receive function, and its main operation, which detects people and attempts to predict their path. The signal transmit function uses previously obtained information about the target's path, as well as relevant node id and data validity information, and packages and broadcasts this information through the RF 433MHz transceiver using the VirtualWire library. The signal receive function uses the same library and an RF 433MHz Receiver to receive signals from surrounding nodes. These signals are then processed and sorted to obtain information about nearby targets. The environment check process simply checks for fog. Both the environment check procedure and the signal transmit procedure make use of the protothreading functionality provided by the TimedAction library, while the receive procedure and the main operation run on the primary "thread". The main operation uses sensor input and the system's supporting procedure to provide light for nearby people, while attempting to predict their path. The supporting procedure is a time management procedure, which keeps track of all relevant time information in the system. The main operation is explained with more detail below.

The main operation provides light for people directly in front of a node, and makes estimations about the position of people. If there is a low level light in the atmosphere, the node will provide either a low or high amount of light, based on human presence. If there are people in front of the node, the node provides high light, and if no one is in front of the light, the node provides low light. If there is adequate light in the atmosphere, the node keeps lights off. With the use of detection sensors and the system's time management procedure, the system is able to make basic predictions about a target's speed and direction on a linear path. Using this information, nearby nodes can light a path in front of a target or group of targets shortly before the target or group of targets arrives at any given point in the path. The system uses two detection sensors to determine the direction of movement of a target on a path by keeping track of the order in which these sensors are triggered. The system keeps track of the time a target is in front of both sensors and calculates the target's speed, as well as the time it should take before the target reaches the next node. In addition to the time information obtained from the sensors, speed and time calculations use information about the sensor's coverage area and the distance between nodes. The calculated speed value is converted to a time delay value using the user-defined distance between nodes, which is sent using the transmission procedure. The appropriate relays, and subsequently the appropriate lights, are powered using sensor input from the base sensors and data from nearby nodes. An identification system is used to identify specific nodes, which grants the system the ability to create a path of light in front of the target. Node ID's, sensor coverage, and distance between nodes are assigned by the user at the time of implementation. This path prediction procedure will only function with light human traffic, since the sensors used cannot differentiate multiple people.

The accompanying relays are used if there is inadequate light circuit infrastructure. Certain combinations of relays will power our light circuit appropriately, Contained within the light circuit are two 40W bulbs and an LED strip. The LED strip is powered when the controller determines the "low light" setting is appropriate. All lights are powered when the controller determines the “high light” setting is appropriate. All lights are off when the controller uses its “no power” setting. An additional “fog light” setting is included to provide more appropriate light in the case there is fog surrounding the node. The fog light setting is the same as the “high light” setting, only its 40W bulbs are brighter.

V. Project Achievements

The final implementation of the system is a low-cost, energy efficient human-detection based light system that is able to use a variety of different human-detection sensors and environmental sensors to perform its functions. The low cost of the entire system is due to its potential for cheap hardware, and for its ability to adapt to existing infrastructure. The system maintains energy efficiency by limiting its functionality to when humans are nearby. This strategy of human-detection based functionality is also much safer than current energy consumption reduction strategies, such as turning off lights altogether for long periods of time.

The system is responsive to the environment. Lights turn on only when atmospheric light is low enough to justify light, and turn off when there is an adequate amount of light in the atmosphere. The system detects fog and responds by providing nearby people with additional light.

Basic path prediction on a linear path is achieved by using any combination of a variety of different detection sensors, and is accurate to a reasonable degree. Assuming the target is traveling at a constant speed, and there is roughly ten meters between nodes, the system is able to estimate a target's position within a meter, which is a feat given its potential for cheap hardware. Using the target's position, the system is able to use its many nodes to provide light on the target's path before the target arrives at any given point in the path.

VI. Future Work

Some improvements can be made to the system to improve its effectiveness and decrease the burden of maintenance and deployment. A better, more intuitive interface can be used to increase ease of maintenance and deployment. A user interface could provide the user with an intuitive way of assigning a node's ID, sensor coverage area, and distance between itself and neighboring nodes. Better noise detection and reduction techniques can be used to increase the accuracy of speed and position calculations, which increases the effectiveness of the path prediction procedure. Support for additional detection sensors, in addition to the existing UltraSonic sensors and PIR sensors, can be added for better modularity. Considering the lack of strength of our transmitters and receivers, it might be useful to build simple antennas for more effective data transmission. As an alternative to wireless data transmission, existing infrastructure can be adapted to allow wired communication between nodes. However, this could prove to be costly if infrastructure does not already exist. By using existing infrastructure, one could create a centralized controller to facilitate communication between nodes. The current implementation of the system uses two 100V AC power plugs, but with additional circuitry and adapters, this can be cut down to one.