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Greenhouse microclimatic environment controlled by a mobile measuring station

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ABSTRACT

This paper investigates a greenhouse microclimatic environment controlled by a mobile measuring station with the aim of improving performance by using wireless sensor networks (WSN) technology. The algorithms for the mobile measuring station that perform navigation tasks are called Bug algorithms. The existing potential field method based algorithms are improved with an RSSI signal propagation model and implemented on a two-wheel driven robot developing system and their performances are measured and analyzed. The implementation part is done on Boe-Bot equipped with SunSPOT enabling the wireless control ability. The control surface is generally made with LabVIEW and a relational database. Control strategy selection system is supported by Fuzzy Analytic Hierarchy Process (FAHP). Navigation of the mobile measuring robot can be done manually, relying on the visual data from the robot's camera, or it can be switched to automatic mode where the developed algorithm does the navigation job. Mobile robot navigation is based on the potential field method considering a wide range of energy-aware parameters.

1. Introduction

The aim of this paper is optimization of energy consumption during operation of greenhouses. The proposed system has the option of gathering and monitoring climate parameters related to the microclimatic environment of plants, both inside and outside of the microclimatic environment using wireless sensor networks. The area of research within the controlled microclimate environment is an autonomous mobile measuring station that collects climate data within the environment. For the movement of the robot during measurements in a dynamic environment, an improved method of navigating the mobile monitoring stations was developed based on the potential field method. Mobile robot navigation is based on the potential field method in combination with the received signal strength of the WSN (Wireless Sensor Networks) used as markers to guide the robot. The combination of localization using signal strength of WSN nodes and methods of potential fields leads to the possibility of application of this method in an unknown dynamic environment. From the starting point, the mobile robot should find a path to the target in a dynamic environment, avoiding any obstacles. One of the contributions of research is to improve the performance of mobile robot navigation in an unknown environment. In the interest of optimal energy consumption during operation of greenhouses, a new model of an expert system for managing microclimate multi-criteria decision making based on the application of fuzzy rules is proposed. Six control strategies were developed for managing greenhouse climate and depending on the measured climatic conditions, the choice of an optimal control strategy shall be made by the energy consumption parameter. After a short introduction, Chapter II gives an overview of other researchers' solutions and experimental data. Chapter III describes the environment realized for the purpose of testing the current project. Chapter IV gives an overview of the proposed control strategy selection system based on the Fuzzy Analytic Hierarchy Process (FAHP). Chapter V shows an evaluation of the expert system used in control strategy selection. Chapter VI presents experimental results and analysis of collected data. Chapter VII shows a discussion about the mobile automated greenhouse control system. We concluded Chapter VIII with an overview of the production cycles of the implemented greenhouse environment.

2. Related work

The navigation method could manage the robust mechanism guiding the robot along the near-shortest path in static or dynamic

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environments, and no fully informed map is needed. There are few groups doing research work in a greenhouse control system, e.g. [1], [2] and [3]. They use various devices for air temperature, relative humidity and soil temperature measurements with a wireless sensor network. They have also developed a web-based plant monitoring application. A greenhouse grower can read measurements over the Internet, and an alarm will be sent to the owner's mobile phone by SMS or GPRS if some measurement variable changes rapidly. In the test environment, six nodes are deployed into two rows 12.5 m apart from each other. One mesh node works as a repeater and improves the throughput of communication. A bridge node gathers data from other sensor nodes, which transmit temperature and relative humidity measurements in one-minute intervals. Our implementation differs from other developments in the use of a mobile measuring agent, which provides flexibility and robustness for the system. Autonomous robots may be operated by different navigation schemes. The best results were given by a modified implementation of the potential field method. Robot control architecture provides rules, guiding principles and constraints for organizing a robot control system, programs and control algorithms so it can be autonomous and achieve goals [4]. The requirements featuring a WSN are expected to satisfy in effective agricultural monitoring concern both system level issues like unattended operation, maximum network life time, adaptability or even self-reconfigurability of functionalities and protocols and the final user needs e.g. communication reliability and robustness, user friendly, versatile and powerful graphical user interfaces. Serodio [5] developed and tested a similar distributed data acquisition and control system for managing a set of greenhouses. Several communication techniques were used for data communications. At a lower supervision level, inside each greenhouse, a WLAN network with a radio frequency of 433.92 MHz was used to link a sensor network to a local controller. A controller area network (CAN) was provided to link an actuator network to the local controller. Through another RF link (458 MHz), several local controllers were connected to the central computer (PC). High-level data communication was provided through Ethernet to connect the central PC to a remote network. Feng [6] implemented a wireless data acquisition network to collect outdoor and indoor climate data for greenhouses. Several solar-powered data acquisition stations were installed indoor and outdoor to measure and monitor climate data. RF links were established among multiple (up to 32) SPWASs and a base station, which was used to control the SPWASs and to store the data. Liu and Ying [7] reported a greenhouse monitoring and control system using Bluetooth technology. The system collected environment data from a sensor network in a greenhouse and transmitted the data to the central control system. Mizunuma [8] deployed a WLAN in a farm field and greenhouse to monitor plant growth and implemented remote control for the production system. They believed that this type of the remote control strategy could greatly improve productivity and reduce labor requirements.

3. Working environment, technology and methods

The applications for WSNs are many and varied. They are used in commercial and industrial applications to monitor data that would be difficult or expensive to monitor by using wired sensors. They could be deployed in wilderness areas, where they would remain for many years (monitoring some environmental variable) without the need to recharge/replace their power supplies. They could form a perimeter about the property and monitor the progression of intruders (passing information from one node to the next). There are many uses of WSNs. Typical applications of WSNs include monitoring, tracking, and controlling. Some of the specific applications are habitat monitoring, object tracking, nuclear reactor controlling, fire detection, traffic monitoring, etc. In a typical application, a WSN is scattered in a region where it is meant to collect data through its sensor node. The WSN-based controller has allowed a considerable decrease in the number of changes in the control action and made a study of the compromise between quantity of transmission and control performance possible. Fig. 1 shows our greenhouse testing environment. The greenhouse protects plants from extreme weather conditions. However, if the period of daylight prevents the photosynthetic activity, the plants do not grow [9]. Horticultural lighting allows the grower to extend the growing season. It enables a year-round production of plants or makes it possible for the grower to start sowing in early spring and continue season until the first frost [10]. Plants need about 10-12 hours of light to improve growth.

Motion control of mobile robots is a very important research field today, because mobile robots are a very interesting subject in both scientific research and practical applications. In this paper, the object of remote control is the Boe-Bot vehicle. The vehicle has two driving wheels and the angular velocities of the two wheels are controlled independently. When the vehicle moves towards the target and the sensors detect an obstacle, an avoiding strategy is necessary, as in [11], [6] and [12]. The host system is connected to the mobile robot with the SunSPOT module. A remote control program has been supported by graphical user interface shown in Fig. 2. As to the greenhouse climate control problem, the system has

Fig. 1. Crops in the greenhouse.