Big data system for disaster warning of solar greenhouse vegetables

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Abstract

Background: Solar greenhouses are very popular in the north of China as a way of meeting the demand for fresh local winter vegetables. Nonetheless, they are more susceptible to biological and meteorological disasters, such as diseases, pests, fog, haze and cold temperatures. Although we have deployed many record keeping equipment and weather stations, we have lower efficiency of usage on data. Big data has great potential in the future. Thus, our aim is to investigate a big data system for disaster forecasting and control to efficiently capture long-term and up-to-the-minute environmental fluctuations inside greenhouses.

Methods: A greenhouse disaster survey database was designed from the most important place of solar greenhouse vegetable production, that is the area around Bohai Harbor, including Beijing, Tianjin, Shandong, Hebei and Liaoning Provinces. The comprehensive survey provided large amounts of data, such as greenhouse distribution and environment parameter monitoring, for the system. The authors developed and integrated some disease, pest and meteorological disaster warning models using disaster-chain theory. The system was developed using C# in .NET framework.

Results: A big data system for greenhouse vegetable disaster was developed combing with monitoring data for diseases and pests, meteorological data and production record data based on the internet of things, while visualization results were illustrated to provide a reference for the prevention decision. The system was applied in Beijing, Tianjin, Hebei, etc.

Discussion: The present system proposes a meteorological disaster framework which includes warning and management of related diseases and pests. Its innovation is in the use of disaster chain-styled theory for meteorological risk warning and management based on the idea of data-intensive scientific discovery.

Conclusion: A greenhouse vegetable disaster big data system was designed based on the internet of things and disaster warning models, providing a new meteorological service model to control greenhouse disaster, diseases and pests.

Introduction

China has the largest population in the world, with about 300 million middle class people. The rapid rise of the middle class and rising per capita income in emerging economies are leading to increasing demand for healthy, safe and sustainably produced horticultural products. China is the largest producer for vegetables, about 600 million tons in 2014[1]. At the end of 2016, the total protected production area of vegetable is over 4 million hectares in China. Solar greenhouses are very popular in the north of China as a way of meeting the demand for fresh local winter vegetables. Nonetheless, they are more susceptible to biological and meteorological disasters, such as diseases, pests, fog, haze and cold temperatures. The usual loss for horticultural crops is more than 20% due to pests, and the improper control may result in loss of 50-60%, especially no harvest when the heavy situation occurs[2]. The improper control for diseases and pests affect Agricultural product quality safety.

Traditional pathogen monitoring method is costly, and traditional pest monitoring method needs too much experiences, which is more difficult for the younger farmers. Although we have deployed many record keeping equipment and weather stations, we have lower efficiency of usage on data. On one side, we need Intelligent, automatic tools for pest and diseases urgently, on the other side, IOT, Cloud computing, big data has great potential in the future.

According to the trend of Plant Protection Science, big data will combine the experiment, theory and computing to Data-intensive scientific discovery and Global pest forecast and control. Internet of Things and Cloud Computing are expected to increase this development and introduce more robots and artificial intelligence in farming. This is encompassed by the phenomenon of Big Data, with the characteristics of high volume, velocity, variety and low value plus online that can be captured, analysed and used for decision-making[3]. There are some applications of Big Data in agriculture, such as Monsanto and John Deere have spent hundreds of millions of dollars on technologies that use detailed data on soil type, seed variety, and weather to help farmers cut costs and increase yields[4]. However, there is few cases in solar greenhouse vegetable disease and pest warning.

Thus, our aim is to investigate a big data system for disaster forecasting and control to efficiently capture long-term and up-to-the-minute environmental fluctuations inside greenhouses.

System framework

We designed a big data system for disaster warning of solar greenhouse vegetables based on the complex system of weather-pest-crop-cultivation-facility (Fig.1). The system including the pest detection, crop phenotyping, cultivation record keeping, environment monitoring and facility energy and mass balance process, which is a big data warehouse. Based on this, we can develop plant disease and insect early warning model to guide the precision spraying and microclimate control, to support the internet of things application in plant protection.

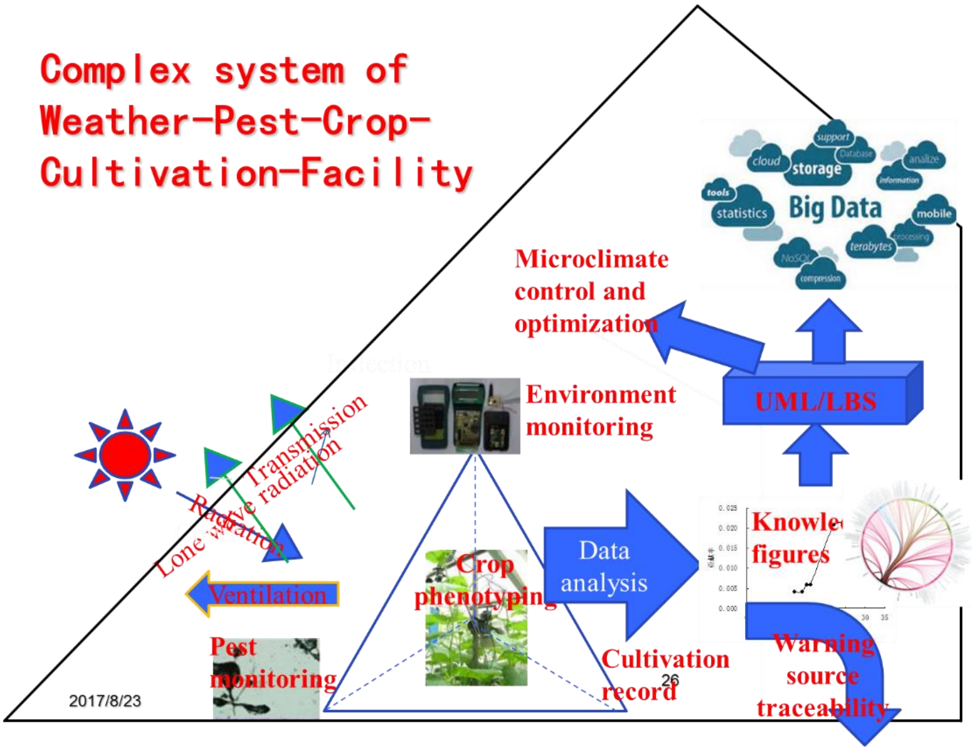

Figure 1. The framework of big data system for disaster warning of solar greenhouse vegetables

Data collection

1. Facility background

A greenhouse disaster survey database was designed from the most important place of solar greenhouse vegetable production, that is the area around Bohai Harbor, including Beijing, Tianjin, Shandong, Hebei and Liaoning Provinces [1,5]. We tried to collect large amounts of data, such as the solar greenhouse area and environment parameter monitoring. The term location based services (LBS) is used to integrate geographic locations (i.e., spatial co-ordinates) with the general notion of services [6]. Infographics will be also used for sharing interesting information.

2. Crop and cultivation

Crop is the core and final product carrier for greenhouse industry, also has significant influence on disease development. In some cases, mature leaves were more resistant to infection whereas in others, younger leaves were less susceptible[7]. The cultivation is very important for disease epidemiology, such as simple, environmentally friendly means for decreasing or eliminating the spread of the disease, by avoiding contact with plants at times when they bear guttation droplets[8]. So we use the traceability system to provide the comprehensive record keeping of crop and cultivation in greenhouses[9].

3. Environment

The greenhouse is a complex with physical, chemical, and biological processes taking place simultaneously, and each process reacting with different response times and patterns to environmental factors[10]. Thus, we will combine the outside weather stations and inside sensors for greenhouse environment monitoring. To calculate the solar radiation in the greenhouse accurately where lack for environment sensors, then could acquire the temperature changes in the greenhouse, and did an early warning of cucumber diseases, a mathematical model was established based on the factors such as time difference, air quality and the transparency coefficient of the atmosphere. The solar radiation outside of the greenhouse was calculated by using this model and solar radiation outdoor, and then the solar radiation in the greenhouse was calculated based on the influence of PE film on the solar radiation transmittance, and then the model was verified by the measured data at a greenhouse in Beijing, China.

4. Diseases

It is urgent need to find the disease before the symptom occurrence. In recent years, thermal infrared imaging technology has a wide application in biological and abiotic stress testing. It can reflect the leaf temperature distribution caused by leaf wetness, therefore, we can use the thermal infrared imaging estimate leaf wetness and pathogen infection early warning. Now the price of thermal camera has been decreased fast, such as some affordable, high-performance thermal imaging for smartphones with about $500; then it is potential to apply this technology to obtain continuous thermal images for online detection of plant disease in greenhouses.

5. Pest

The prediction and forecast is an important prerequisite for the integrated pest management (IPM), to improve the accuracy of prediction and forecast of pests, the automatic monitoring device and the automatic identification system of pests are developed to provide a valuable reference for the integrated pest management (Fig.2).

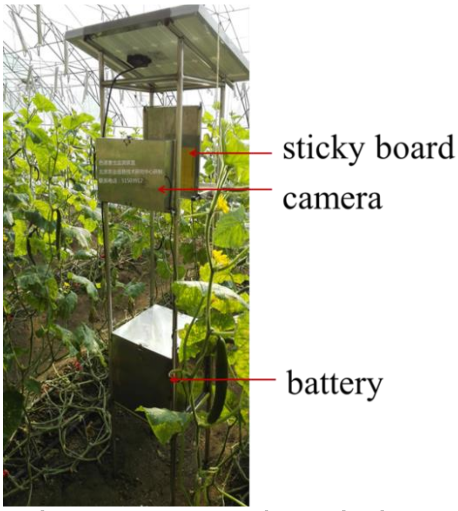

Figure 2. An automatic monitoring device for greenhouse pests

6. Data analysis

According to the trends in plant protection science, the discipline has originated from field survey and experiment, then formed the disease epidemiology and insect ecology to use mathematical model to describe the phenomenon; at last several decades, ICT application has made computer simulation more popular to develop automatic model; nowadays, big data and artificial intelligence become hot topics and provide potential for data-intensive scientific discovery with global pest forecast and control. The authors have developed some disease and meteorological disaster warning models, such as for cucumber downy mildew[11] and meteorological disaster[2]. The primary infection and latent period warning models for downy mildew, powdery mildew and grey mildew were validated using the results from the leaf temperature and relative humidity model; then, the estimated disease occurrence date of disease was compared with the actual disease occurrence date from field observations. Moreover, various models are summarized according to the reference analysis. We will try to use machine learning method, such as deep learning and Bayesian network to optimize the early warning model of disease and pests to improve the accuracy and precision in practice.

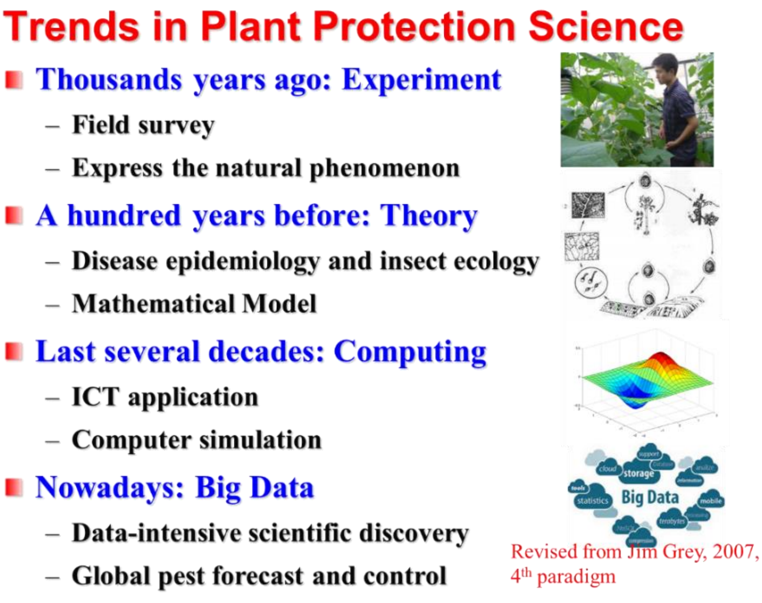

Figure 3. Data analysis progress for plant protection

7. Data services

A forecast warning system of greenhouse vegetable disaster was developed using Visual Studio 2010 and SQL Server 2008 (Fig. 4), which combined with monitoring data of disease and pest, meteorological data and production record data based on internet of things, and visualization results were illustrated to supply reference for prevention decision. The system has been applied in Beijing and Tianjin. On November 2015, Haze weather appeared in Beijing and Tianjin leaded to abnormalities of plant growing, downy mildew and botrytis. The system warned the cucumber downy mildew on the early November, and then suggested the farmers to control the humidity, so that the damage of greenhouse vegetables was reduced without heavy occurrence of cucumber downy mildew. Tianjin Climate Center published the agro-meteorological specific service report titled “Continuous sunless disaster affects the facility agricultural production in Tianjin” on Nov 17, 2015, based on the system warning results[2].

Figure 4. Meteorological Risk Management System for greenhouse vegetable

Discussion and conclusion

In recent years, facilities agriculture has become the highest efficiency part in China’s agriculture, however, the facilities crop production is highly dependent on climate conditions and influenced by the disaster weather strongly. Therefore, it’s significant to assess the impact and risk of meteorological disasters on the facilities crops scientifically and reasonably in agricultural production[12]. It is particularly urgent to provide farmers with meteorological risk management technology. Big data are being used to provide predictive insights in farming operations, drive real-time operational decisions, and redesign business processes for game-changing business models[3]. According to the complex system of weather-pest-crop-cultivation-facility, plus the huge amount of real time monitoring data, big data technology could be useful for developing some applications for providing a new meteorological service model to control greenhouse disaster, diseases and pests.

A big data system for greenhouse vegetable disaster was developed combing with monitoring data for diseases and pests, meteorological data and production record data based on the internet of things, while visualization results were illustrated to provide a reference for the prevention decision. The system was applied in Beijing, Tianjin, Hebei, etc. The present system proposes a meteorological disaster framework which includes warning and management of related diseases and pests. Its innovation is in the use of disaster chain-styled theory for meteorological risk warning and management based on the idea of data-intensive scientific discovery.

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