TELECOMMUNICATIONS FOR DATA COLLECTION AND DISSEMINATION IN AGRICULTURAL APPLICATIONS

Q. Zhang  
*Department of Agricultural and Biological Engineering, University of Illinois, USA*

R. Ehsani  
*Citrus Research and Education Center, University of Florida, USA*

**Keywords:** Wired communication, wireless communication, serial bus, USB, CAN bus, LAN, RF, IrDA, Bluetooth®, WiFi, on-farm networks.

**Contents**

1. Introduction  
2. Data Collection in Agriculture Production  
3. Wired Data Communication in Agriculture  
   3.1. Wired Data Communication Methods  
   3.2. Serial Bus Communication  
   3.3. Computer Networks Communication  
4. Wireless Data Communication in Agriculture  
   4.1. Point-to-Point Communication  
   4.2. Point-to-Multipoint Communication  
5. Data Telecommunication Technology in Agriculture  
   5.1. Technical Advantages of Telecommunication  
   5.2. Disadvantages and Problems of Telecommunication  
   5.3. Implementation of Telecommunications in Agriculture  
   5.4. Applications of Telecommunications in Agriculture  
6. The Future of On-farm Data Telecommunication  

**Summary**

The advances in computers, machinery and electronics, as well as agriculture production technologies have transformed U.S. agriculture from a state of broad scale mechanization to a state of mechanization with precision. The implementation of such technology advancements demands for effective and efficient data telecommunication capabilities, both wired and wirelessly.

This chapter intends to provide an overview of existing wired and wireless data telecommunication technologies applicable to modern agricultural applications. The basic principles and features of some commonly used data communicating means, such as serial bus, universal series bus, CAN bus, RF, IrDV, Bluetooth®, WiFi, LAN and WLAN, are introduced here. A few examples of using the introduced data telecommunication methods in agricultural applications are also provided.
1. Introduction

As one of the most important engineering achievements in the 20th century, agricultural mechanization has greatly improved farming efficiency and helped to produce sufficient foods to feed the people of the world. The new challenges to today’s agriculture include the decline in cultivated land, a reduction in skilled farm workers, more rigid environmental protection requirements, and many more people to feed. The advances in precision agriculture and agricultural machinery, as well as in information technology, are transferring agricultural production from a state of broad scale mechanization to a state of mechanization with precision. Precision agriculture provides agricultural producers a promising method for maximizing profitability through optimizing production based on small grids of a field. For example, farmers are now indeed capable of fertilizing different parts of their field at different rates quickly and efficiently to achieve a maximum return on their farming costs. To fully benefit from the advancements in precision farming technology, it is essential for site-specific production information to be displayed “on-the-go” on the machinery while the producers are performing various field operations. Telecommunication and dissemination of collected data is one of the key elements in automated real-time precision farming operations.

The convergence of sensing, computing and communication technologies for agricultural applications has led to the creation of a new technology — agricultural infotronics systems. An agricultural infotronics system (AIS) is a framework of wirelessly networked on-farm production data management systems.

The basic functions of AIS are to collect, process, and transmit the “ready-to-use” site-specific production data to the user on the machinery while performing the field operation. For instance, when an agricultural sprayer is applying nitrogen on the field, the AIS will sense the location of the sprayer in the field, and supply an appropriate prescription of nitrogen for the specific site to the sprayer wirelessly and in real-time to support precise variable rate nitrogen application. To accomplish this task, a bare-bone AIS consists of a GPS receiver for collecting the sprayer location data, a database for providing site-specific nitrogen prescription data, and a data dissemination network for real-time data communication. Similar to the variable rate nitrogen spraying operation, almost all the agricultural production operations are implemented using mobile agricultural equipment, such as tractors, sprayers and combine harvesters, the telecommunication for data collection and dissemination plays a critical role in an AIS.

This chapter aims to provide an overview of telecommunication technologies applicable to agricultural infotronics system. The following sections are planned so that Section 2 will review data collection technologies commonly applied in agricultural production, Section 3 will describe data dissemination technologies commonly applied on agricultural machinery, Section 4 will explain the basic technologies for on-farm networking, Section 5 will introduce a few successful examples of applying data telecommunication technologies in support of effective site-specific agricultural production, and Section 6 will briefly discuss the technology trends in data telecommunication and their applications to agricultural production.
2. Data Collection in Agriculture Production

Field data collection is very important for efficient precision operations in agriculture production; and reliable and prompt data communication between sensing and data processing units is essential to make the sensed field data useful to operators in the field. Machinery positioning in the field during operation is one of the most common field data collection tasks in today’s agriculture production. The machinery position provides the essential information for all kinds of site-specific management and provides the critical information for machinery navigation. GPS receivers are widely used on agricultural machinery to measure the absolute position in global coordinates directly using satellite-based positioning technology. In some applications, the relative position of the machinery to the travel direction is also very important. In those cases, inertial sensors are often used to determine the relative position. To improve the positioning accuracy and robustness, an integration of GPS and inertial sensors can provide a complementary correction for agricultural vehicle applications. Such an approach, that is, using multiple positioning sensors, could provide precise navigation information to guide a piece of agricultural machinery traveling along the crop rows in conducting various farming operations. Kalman filter technology is often applied to fuse the signals from the complementary sensors for abstracting robust and accurate data to support real-time field operations.

Field data are normally collected either during regular production operations, such as the site-specific yield data collection during the harvest, or from special data collection operations, such as soil compaction surveys. While some of the data can be automatically collected using a computer controlled data acquisition system, many of the field data collections have to be done manually limited by the sensing technology. In general, field data management for precision farming consists of a four-step process.
of field data acquisition, data transportation from mobile devices to an office computer for processing, data analysis, and data transportation from the office computer to an on-machinery device to support the production operations (Figure 1).

Other than being time consuming and requiring special skills requirement in processing field data, the off-line data process illustrated in Figure 1 is another major obstacle in supporting efficient and effective agriculture production. To overcome these difficulties, a wirelessly networked agriculture data management system can automatically manage the data to collect, transport, and present agriculture production data during different farming operations. Figure 2 shows the conceptual illustration of such an automated field data management system. According to the data management processes illustrated in the figure, the field data collection is automatically implemented using the computer controlled data acquisition system installed on operating agricultural machinery in the field. The collected data is then transported wirelessly to a remote data processing center for analysis in real time using some pre-developed precision agriculture data management tools. Appropriate field operation instructions are derived based on the processed real-time field data and delivered back to the operating machinery for implementation. The core of this automated field data management system is data processing tools, and the essential infrastructure of the system is the data communication (either wired or wireless).

Figure 2: Conceptual illustration of automated field data management using AIS
3. Wired Data Communication in Agriculture

3.1. Wired Data Communication Methods

Wired data communication is the basis for all data communication. In computer-based data acquisition, the computer has to accept input signals and/or send output signals to regulate the data acquisition via some type of wires or cables. The data transmission over wires and cables is also called the wired data communication, in comparison to the wireless data communication. It is common to call a device either sending signals to the computer or receiving signals from the computer the peripheral. Some examples of peripherals are the display monitor, the sensors, and the actuators. Normally, data communication between the computer and the peripherals can be achieved either in parallel or serial mode. In data collection and dissemination operations on agricultural machinery, the data communication is always carried in serial mode.

The serial mode of data transmission sends bits of data one at a time along a single conductor in the format of a high or low voltage signal, and is mandatory for transferring data to and from data storage devices. Some terms frequently used in serial data transfers include mark, space, character, and cluster. A mark is always represented by 5 V and is a logical 1, and a space is always represented by 0 V and is a logical 0. The marks and spaces are grouped into a character, often one byte of data consisting of eight marks and spaces. A character is normally separated from others using a start bit (a space), a stop bit (a mark) or a parity bit. The assembly of the start bit, the character, the stop bit, and parity bit is defined as a cluster. The rate of data communication is determined by how many bits per second can be transmitted, and is defined as the baud rate. Some typical baud rates for wired serial communication are 100; 300; 600; 1,200; 2,400; 4,800; 9,600 and 19,200 baud.

Because of the cluster structure, data communication in a serial mode can be transmitted intermittently, and each device can transmit data at the time it needs to, just like two people talking over a telephone. This type of data communication method is termed asynchronous communication. In asynchronous communication, data flows along the line in spurts— one cluster at a time, as illustrated in Figure 3. During the data communication, the transmitter sends a cluster (eight bits of data, for example) bounced by the start and stop bits and then may wait a period at its own discretion. Following transmission of a cluster, the final stop bit leaves the line in a mark status, a condition in
which it remains until the next start bit switches the line to a space status. In the case of continuous data transmission, the waiting time will be zero. An important characteristic of asynchronous communication is that the transmitter and receiver need essentially the same clock frequency so the characters will not be misunderstood.

Bibliography

Deveson, T. (2001). Decision support for locust management using GIS to integrate multiple information sources. First Australian Geospatial Information and Agriculture Conference, Sydney: 361-374. [This paper introduces the use of a GIS-based decision support system (DSS) to coordinate the collection, processing and display of a range of spatial data for an agricultural application.]

Flores, A. (2003). Speeding up data delivery for precision agriculture, ARS Magazine, 51(6): 17. [This paper introduces a high-speed wireless networking system that will allow farmers to download aerial images via the Internet onto their personal computers, laptops or hand-held PCs in a cost-effective and efficient way.]

Fukatsu, T. and M. Hirafuji. (2003). Development of field servers for a field monitoring system. Agricultural Information Research, 12(1), 1-12. [This paper discusses the role of information technology (IT) and its practical contributions to agriculture, introduced Japan's experiences in the use of IT in agriculture, and identified the requirements and the issues needed to make practical use of IT systems for the agricultural domain.]


Lee, W.S., T.F. Burks and J.K. Schueler. (2002). Silage yield monitoring system. ASAE Paper No. 021165. St. Joseph, Mich.: ASAE. [This paper introduces the implementation of a Bluetooth module (wireless transmission) to transfer moisture sensor data to a host computer in a real-time yield mapping during silage crop harvesting.]


Marsili, R.T. (1999). SPME-MS-MVA as an electronic nose for the study of off-flavors in milk. *Journal of Agricultural and Food Chemistry, 47*(2), 648-654. [This paper introduced the integration of a solid-phase microextraction, a mass spectrometry and a multivariate analysis method to form an electronic nose for differentiating normal-tasting food and beverage samples from those containing off-flavors and malodors.]


Mizunuma M., T. Katoh, and S.-I. Hata, (2003). Applying IT to farm fields - a wireless LAN. *NTT Technical Review, 1*(2), 56-60. [This article describes the development of a wireless LAN in farm fields and a pilot program using the LAN to map plant growth and implement greenhouse remote control.]

Pocknee, S., V. Garrick, and C. Kvien. 2004. Wireless Local Area Network Technology for On-farm Monitoring and Control. Proceedings of the 7th International Conference on Precision Agriculture, Minneapolis, MN, July 25-28. [This paper describes both the potential benefits and the current limitations of IEEE 802.11 based WLANs for on-farm use.]


Zhang, Q., S. Han and J.F. Reid. (2000). Agricultural infotronic systems for precision crop production. In: Shibusawa, S., M. Monta, and H. Murase (Eds.), *Bio-Robotics II*, 2000, IFAC, Osaka, Japan, Pp. 295-298. [This paper provides the original definition of the agricultural infotronic systems (AIS) concept and illustrated AIS application on an automated wheel-type agricultural tractor.]
Biographical Sketches

Prof. Qin Zhang was born in China. Zhang received a Ph.D. degree in agricultural engineering from the University of Illinois at Urbana-Champaign, Urbana, Illinois, USA in 1991; a M.S. degree in agricultural engineering from the University of Idaho, Moscow, Idaho, USA in 1988; and a B.S. degree in mechanical engineering from Zhejiang Agricultural University, Hangzhou, China, in 1982.

He is currently an Associate Professor of Agricultural and Biological Engineering at the University of Illinois at Urbana-Champaign, Urbana, Illinois. Before joining the faculty of the University of Illinois at Urbana-Champaign, he has worked as a Sr. Research Engineer at Caterpillar Inc., Peoria, Illinois. Prior to that he has also worked as a Sr. Project Engineer with Automated Automation Corporation; a Post-doctoral Research Associate with the University of Illinois at Urbana-Champaign; and an Instructor with Zhejiang Agricultural University in China. He has published over 70 peer reviewed journal articles and over 140 technical papers at various international and national professional conferences. His current areas of research include agricultural equipment mechatronics, agricultural infotronics and agricultural automation.

Prof. Zhang is a member of the American Society of Agricultural and Biological Engineers, the Society of Automotive Engineers, and the Institute of Navigation.

Prof. Reza Ehsani was born in Iran. Ehsani obtained a Ph.D. degree in Biological and Agricultural Engineering from the University of California, Davis, USA in 2000, where he worked on precision agriculture applications for high value crops. Ehsani has also obtained a M.S. degree in 1992 and a B.S. degree in 1988 in Agricultural Engineering from Tehran University, Iran.

He is an Assistant Professor of Agricultural and Biological Engineering at the University of Florida/IFAS Citrus Research and Education Center (CREC). He was an assistant professor and a precision agriculture specialist at the department of Food, Agricultural and Biological Engineering at the Ohio state University before joining the University of Florida. His current areas of research include developing and improving yield monitoring systems for citrus mechanical harvesters, applications of wireless sensor networks for citrus groves, application of GPS/GIS for grove management, and development of soil and plant sensors. He also works on the development of education materials on the application of GPS/GIS and sensor technology for citrus production, and organizes grower conferences on precision agriculture and mechanical harvesting for citrus.

Prof. Ehsani is a member of the American Society of Agricultural and Biological Engineers.