NTT R&D Initiatives for Applying IT to the Primary Industry Sector: Farm Data Distribution System

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Abstract

Information technology (IT) has now been applied to numerous areas including government, distribution, and medicine to name just a few, and the primary industry sector has been no exception. In this special issue we will explore some recent NTT R&D initiatives seeking to address the serious issues facing the farming sector today—aging of the agrarian work force, environmental pollution, and uncertainty about the safety of food products—through the application of IT.

1. National efforts to apply IT to the farm sector

Japan has enacted legislation and instituted numerous policies in an effort to help address some of the difficult issues now facing the farm sector: Japan's diminishing ratio of food self-sufficiency, the shrinking farm population, and liberalization of agricultural markets (Table 1).

The adoption of the "New Basic Agriculture Law" (Basic Law on Food, Agriculture and Rural Areas) in 1999 marked a shift in emphasis away from the farmers, who had been at the focus of the old law, to consumers. It also underscored such basic principles as stability of the food supply, greater diversification of farming enterprises, and continuous development and promotion of farm communities [1]. The next year (2000), Japan passed the "Basic Law on the Formation of an Advanced Information and Telecommunications Network Society" with the goal of actively promoting a society in which all sectors and all citizens can have access to and enjoy the benefits of information technology.

Based on these two laws, the government declared in 2001 a specific policy objective of "applying IT to the agriculture, forestry, and fisheries sectors in the 21st century." Emphasizing expanded use and availability of digital contents, deployment of IT infrastructure, improved data and IT literacy, and other key provisions, the guideline signals Japan's commitment to extend IT to the agricultural sector as a matter of national policy [2]. In another development against the backdrop of recent outbreaks of E. coli O157 and BSE (*i.e.*, mad cow disease) and heightened concern of consumers and the public at large over organic and pesticide-free farming and other food safety related issues, legislative progress has been made to ensure food safety with the Revised JAS Law, which makes it mandatory to identify the country of origin on the labels of fresh food products, and with the Emergency Countermeasures Relating to Bovine Spongiform Encephalopathy (BSE), which mandates the tagging of all cattle and accurate tracking of each animal with a data management system.

2. Initiatives on the farm

There has been significant improvement in the utilization of farmland in recent years fueled by advances in geographic information systems (GIS), soil sensing, and other scientific techniques, as well as growing public demand for better environmental protection. GIS-based modeling can be used for mapping tracts of land to show the distribution of soils, crop yields, parasites, and so on, and there has been good progress made in the investigation and adoption of modern ecologically sound farming practices (precision farming) that achieve sustained productivity with sharply reduced use of chemical fertilizers and pesticides along with improved economics [3]. And along with the phenomenal technological revolution

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Table 1. Recent farm policy trends.

Year	Law	Policy guideline
1998		Agricultural administration revised network • Continue, expand domestic farm production • Establish food policies from the standpoint of consumers • Ensure and set aside farm land, water, *etc.* for agriculture • Ensure, train agricultural workers • Stabilize, develop farm management • Develop, disseminate new technologies • Fully exhibit natural recycling functions of agriculture • Fully exhibit diverse functionality inherent in farming and farming communities • Reassess agricultural groups
1999	Basic Law on Food, Agriculture and Rural Areas • Ensuring stable food supply • Demonstrating diverse functionality • Continuous development of agriculture • Revitalization of farm communities	
2000	Revised JAS Law • Labeling of genetically modified foods • Mandatory labeling of country of origin on fresh products Three Agriculture Environment Laws • Rationalize management and promote use of animal waste products • Promote introduction of farm production methods that are stable and durable over the long haul • Promote appropriate use of special fertilizers	
2001		Applying IT to the agriculture, forestry, and fisheries sectors in the 21st century • Establish business management practices based on various kinds of data • Reduce distribution costs • Vitalize agriculture, forestry, and fisheries areas
2002	Emergency measures addressing BSE • Use of meat and bones in feed is prohibited, subject to BSE testing • Implement ear-tagging, individual livestock data management	Food and farm rejuvenation plan • Ensure safety and confidence in food products • Speed up structural reform of agriculture • Promote compatibility and interchange between cities and farm, mountain, and fishing communities

symbolized most dramatically by the remarkable penetration of the Internet, we have seen a growing trend for agricultural producers to use the Internet to directly contact consumers and sell them products that are exactly tailored to their preferences.

It is a safe assumption that digitization and use of IT and sensing technologies will become increasingly important at each step from production to processing to distribution to consumption in terms of boosting productivity, establishing environmentally friendly farming practices, and providing information to consumers regarding the safety of food products.

3. Objectives and challenges of farm data distribution

The objectives and specific content of data distributed at each stage of the food production chain are shown in Table 2.

Various kinds of information are required in the production process in order for farmers to boost productivity and save labor, support business operations and train successors, and achieve ecologically sustainable farming practices. Critical data includes crop-specific information about growing conditions, environmental information including the weather and soil conditions of particular tracts of land, business diagnosis information and agribusiness support data, and information about waste products and land use. Turning next to the processing phase, here too all kinds of information are required regarding quality, hygiene, and collection and shipping of raw materials and regarding the management of manufacturing. In recent years a great deal of interest has focused on HACCP*1 for managing the safety and quality of food. And finally in the distribution and consumption processes, the various types of information listed in Table 2 are required for quality and shipping control, customer management, and food safety control.

One can see that there is an enormous amount of useful data at every stage of the food production

*1 HACCP (Hazard Analysis Critical Control Point) is a scientific control system for identifying and evaluating hazards that might occur throughout the entire food production chain from production, processing, and cooking right up until the food is consumed. The system focuses on preventative measures including identification of critical control points, procedures to monitor critical points, and effective record-keeping.

Table 2. Use of agricultural data: areas and objectives.

Area	Objective	Data content
Production	Boost productivity, reduce labor	Growth data, crop stress data, disease/pest projection data, weather data, soil diagnosis data, individual livestock data, cultivation technology data, new variety data, trial/research results data, quality data (sugar content, milk constituents, *etc.*), crop situation
	Sustainable farming	Soil diagnosis data, farm land use data, waste product data, fertilizer and feed data, cycle-related data (nitrogen, phosphorous, *etc.*)
	Support business, train successors	Farming data, business diagnosis data, labor data, farm equipment use data, materials data, system funding data, market situation data, farm technology data
Processing	Quality, shipping control	Raw materials data, manufacturing control data, HACCP data, shipping data
Distribution	Quality, distribution, customer control	Market situation data, sales data, collection and shipping data, producing area data, consumption trend data, statistical data, customer management data, transportation and delivery data, global agricultural products data
Consumption	Assurance, safety	Producing area data, quality and safety data (expiry dates, components, additives, genetic modification data), production history data, processing data, distribution history data, certification data, and cooking instructions
Other	Promote regional communities, interchange between rural/urban communities, *etc.*	Life style data, health management/medical treatment data, government data, show data, city-rural community interchange related data, school and education data, facilities use instructional data, library and document data

chain, and although it has mostly been the big corporations and organizations that have had the processing capabilities to exploit this information, it would be highly significant if this information were also available to the individual operators who are the primary producers. Indeed, the ability of producers to exploit this valuable data that is available could be instrumental in helping individual farmers break out of the hard circumstances surrounding Japan's agricultural sector.

Table 3 shows the technologies needed to collect, store, process, and distribute these various kinds of farm-related data classified according to how the data might be used. A primary industry data distribution service could be implemented by integrating a communications network such as the Internet with a number of other technologies: sensing technologies (soil, weather, *etc.*), simulation technologies (business, demand, *etc.*), various databases, and data mining capabilities.

The application of IT to agriculture has been hampered by a number of factors, and it is clear that farming has lagged behind other sectors in seeing the benefits of IT. Some of these factors include:

- The industry is largely dependent on local conditions characterized by widely varying data that often cannot be directly utilized by a farming community in another part of the country.
- Farming is controlled to an extent by diverse weather, geographic, and other complex aspects of the natural environment.
- Agricultural products are produced in a large number of grades according to peoples' sense of taste and quality.
- A lot of data relating to the internal mechanisms of organisms and the state of target variables is easily affected by the presence of a sensor, so it is difficult to ascertain the actual conditions.
- The diversity or uniqueness of certain food products is somehow incompatible with e-commerce or other methods that might be used for distribution.
- Content (data) or IT-support software is scarce or altogether lacking.

Indeed, the extent to which IT and sensing technology can be applied to the farm sector will largely depend on how successfully these kinds of impediments can be overcome and functional, cost-effective systems can be made available.

4. Agriculture network

Figure 1 shows a model of a network for the agricultural sector that links the entire food production chain from production to consumption. NTT Research Laboratories are currently focusing their efforts on finding viable ways to digitize production-stage data.

The system features an assortment of sensors (for measuring weather, soil, water quality, and other conditions) and monitoring cameras that are installed outdoors in fields and indoors in greenhouses and barns, which are networked over a wireless LAN providing data and images that are useful to the producer in raising crops and livestock. In addition to the sensor data, the producer contributes a daily record of work and progress on the farm, and this all goes into a farm database. The farmer shares some of the farm database with the local farm cooperative, agricultural

Table 3. Technologies supporting primary industry information distribution.

	Business management	Farm technology	Save labor, automation	Education	Market survey, data transmission	Network sales	Greater business involvement	Teleworking	Tourism	Agri-money	Ecology
Communication network	Internet WWW VPN Intranet LAN	Internet WWW Wireless LAN	Internet WWW Wireless LAN	Internet WWW Satellite com. Intranet Teleconference LAN	Internet WWW CTI Intranet LAN Agent	Internet WWW CTI Intranet Agent	Internet WWW Teleconference Intranet	Internet WWW Teleconference Intranet	Internet WWW Teleconference Intranet Agent		Internet WWW VPN Intranet
Data processing	Business database Data mining	Sensor fusion Agent Knowledge base Neural net Chemometrics CG	Remote medical Multimedia database Example database Image processing Neural net Population knowledge	CAI VR Multimedia database	Multimedia database Data mining Image database PRTR Ambiguous search	Multimedia database Data mining EC GIS Ambiguous search Image search Distributed database Authentication	Business database Data mining PRTR E-manifest		VR CG GIS Multimedia database	VR CG GIS Multimedia database	PRTR E-manifest
Computer science		Fuzzy inference Multi-variable analysis JA Time-sequence analysis			Fuzzy inference Multi-variable analysis	Fuzzy inference Multi-variable analysis					
Sensing		Remote sensing Microanalysis Soil sensor Water quality sensor Weather sensor	Soil sensor Water quality sensor Weather sensor Non-destructive testing Environmental control Remote sensing	Soil sensor Water quality sensor Weather sensor Remote sensing							Weight sensor Odor sensor Soil sensor Water quality sensor
Simulation	Business simulation	Farm management simulation, weather forecasting		Farm management simulation, weather forecasting	Demand forecasting		Business simulation				

CAI: Computer-Assisted Instruction
CG: Computer Graphics
CTI: Computer Telephony Integration
EC: Electronic Commerce
GA: Genetic Algorithm
PRTR: Pollutant Release and Transfer Register
VPN: Virtual Private Network
VR: Virtual Reality
WWW: Worldwide Web

experimental station, and livestock veterinarian, and this data contributes to the establishment of good farm management and technology guidelines. In addition, the information made available by the producer to consumers regarding agricultural chemicals, animal feed, and so on can be used for quality and safety assurance purposes. The ultimate goal is to create an environment where data in many different databases can similarly be mutually accessed including the farm cooperative database, the processing and distribution database, the retail store database, and even more specialized databases such as for the agricultural experimental station.

5. NTT R&D initiatives

Based on these developments, NTT is committed to the pursuit of three basic R&D objectives for the agricultural sector: ecologically sustainable farming, IT-based farming (precision farming), and a food safety

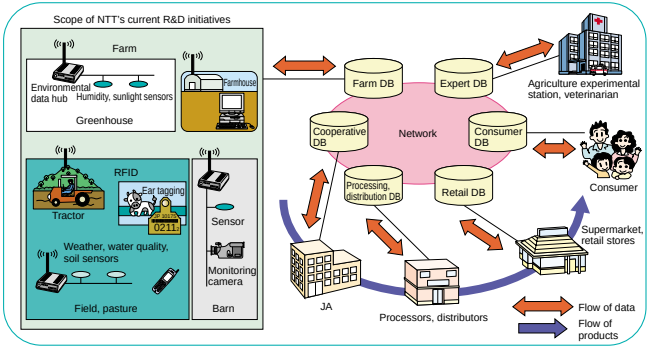

Fig. 1. Model of network for the agricultural sector and NTT R&D initiatives.

network [4]-[6].

Farms and farm communities play the extremely beneficial role of preventing flooding by absorbing and storing immense quantities of water that they use for irrigating fields and immersing paddy lands (Table 4). But on the negative side of the ledger, farmers have used enormous quantities of pesticides and chemical fertilizers over the years to improve productivity and these have ended up as detrimental chemical substances in the soil and human body, and soil and groundwater have also been polluted by simply discarding untreated excreta from livestock. NTT is helping open the way to ecologically sound and sustainable farming practices with the development of an environmental assessment system. This system uses sensing networks and GIS to monitor and analyze the recycling of noxious substances such as livestock excreta that is already becoming subject to increasingly strict laws and regulations (see the article "Applying IT to Farm Fields—A Wireless LAN" on page 56).

NTT initiatives are also helping bring IT to the farm with the development of a system that boosts productivity even with less labor by networking fields and other productive sites with a wireless LAN and deploying various sophisticated sensing technologies. Specific subsystems that are part of this project include a crop growth mapping system utilizing image processing technology, a greenhouse remote control system, a livestock data management system that tags and tracks individual animals, and a cattle barn status monitoring system (described in "Applying IT to Farm Fields—A Wireless LAN" on page 56).

Turning to the food safety network, particularly as it relates to dairy products, NTT has made good headway in the development of a traceability system and information disclosure system that tracks and records safety-related information all the way down the food production chain, then makes the information available to consumers in an easy-to-understand format. The range of safety information captured by the system is comprehensive including animal raising and quality control data from the farm where the livestock is raised, HACCP data from the processing facility, and quality control information from the distributor (see the article "Extending IT to the Dairy Farm" on page 66).

Figure 2 schematically shows how a dairy farm data distribution system might be implemented by applying NTT's three-fold R&D approach to the dairy sector. As illustrated in the figure, this R&D approach will promote the sharing of environmental information among producers, processors, and local governments (environmental cycle); the sharing of business and technological information among producers, testing and research institutes, and farm cooperatives (technology cycle); and the sharing of food safety information among producers, test and certifying

Table 4. Public benefits of farms and farm communities.

Beneficial effect	Valuation amount (yen per year)	
	Nationwide	Mountainous areas
Prevent flooding	2.8789 trillion	1.1496 trillion
Cultivate water resources	1.2887 trillion	602.3 billion
Prevent soil erosion	285.1 billion	174.5 billion
Prevent landslides	142.8 billion	83.9 billion
Organic waste processing	6.4 billion	2.6 billion
Atmospheric purification	9.9 billion	4.2 billion
Climate moderation	10.5 billion	2 billion
Health, relaxation, peace of mind	2.2565 trillion	1.128 trillion
Total	6.8788 trillion	3.319 trillion

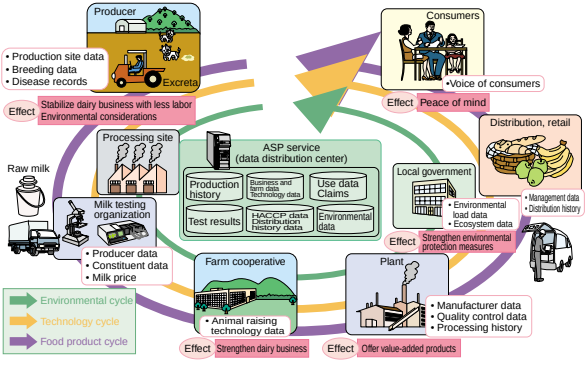

Fig. 2. Concept of dairy farm data distribution system.

authorities, processors, distributors and retailers, and consumers (food product cycle). With this approach, we can implement farm data distribution systems that promote sound sustainable farming practices, business stability that saves on labor, and safe food products.

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