Application of Cloud Computing to Agriculture and Prospects in Other Fields

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Most of the information technology (IT) systems currently used by Japanese farmers are used for duties such as filing tax records and traceability records to meet the requirements of non-farmers in the government and distribution industry. We focused on introducing the latest technologies such as sensors, wireless networks, and Cloud computing to radically revise approaches to agriculture and conduct business feasibility studies to establish a hypothetical model of Cloud services that make a genuine contribution to agriculture. We have conducted demonstration tests with the cooperation of two Japanese farming corporations. This hypothetical model has much in common with on-site operations such as medical/nursing care and maintenance besides agriculture, so we are working to develop it across a broader range of fields. On the basis of the knowledge acquired through actual agricultural operations and subsequent analysis, we describe the affinity between agriculture and Cloud computing and discuss how the technologies used in the demonstration test can be applied to other fields.

1. Introduction

We are currently in the middle of a global recession due to the financial meltdown brought about by the subprime mortgage crisis in the USA. Now that the economic situation has settled down for the time being, attention is being turned once again to the steep rise in the price of energy and food, which is caused by factors such as population growth in newly industrializing countries.

In the Japanese media, agriculture is often cited alongside Japan's aging demographics as one of the largest problems facing the country. Many of the issues associated with agriculture have structural aspects and can be broadly divided into issues related to the Agricultural Land Act, lack of successors to farmland, and diversification of eating habits. Agricultural land issues present a barrier to the participation of new individuals, which is one reason why the average age of producers is over 60. In addition, the westernization of Japanese eating habits and the decreasing consumption of rice and fresh vegetables is bringing about a structural transformation in Japanese agriculture from various different aspects. Annual sales of agricultural products in Japan amount to 8 trillion yen, whereas subsidies from the national budget amount to 3 trillion yen.[1] Although Japan's agricultural technology is said to be the best in the world, it cannot be stated definitively that it is established as an industry. Moreover, now that environmental issues are recognized as global issues, and the future food supply has emerged as a global problem, Japan's agricultural industry is likely to lag behind global initiatives because of its structural problems.[2] Japan's industrial technology is utilized in various areas, and agriculture itself is expected be established as an industry.

At Fujitsu, we aim to introduce information technology (IT) into agricultural practices and connect agriculture into a single large industry in order to contribute to efforts to improve Japan's self-sufficiency in food production and to develop foreign markets for Japan's superior agricultural technology.

In this paper, on the basis of the findings of on-site agricultural studies and their analysis, we discuss the suitability of Cloud computing for agriculture and its application to other technological fields.

2. Agriculture: method and value of entering the field

2.1 Agriculture and IT

The introduction of IT into agriculture has hitherto been performed in areas where farmers have been more or less obliged to use it to comply with government and distribution industry rules, such as filing tax returns and maintaining traceability records. It cannot be said for certain that IT has been useful in actual agricultural production. By focusing on the following two points, we investigated an IT system that should be useful for agricultural production.

- Increased efficiency for agriculture as an industry
- Succession of agricultural technology

As a result of performing fieldwork related to these issues at agricultural locations, we first demonstrated the need to propose examples where the work style of agriculture itself is replaced by production processes such as an improved plan-do-check-act (PDCA) cycle and improved communication & information sharing.

1) Improved PDCA cycle (clarification of workflow such as issuing instructions and reporting)

We have found that the design and implementation of farm work is decided every day on the basis of experience and intuition comprising a large body of know-how gathered by veteran producers over many years of labor. This know-how takes the form of rules such as "If *A* happens, then do *B*." This is the combination of knowledge management that has struggled for many years between production planning and IT in secondary industries, where it is judged to be worth making sufficient effort and its effectiveness is being verified. On the subject of knowledge management, due to the ideal of converting tacit knowledge into explicit knowledge, there is a tendency to end up focusing on how to make better-tasting vegetables.[3),4)] Although this sort of agricultural technology is of course important, it has been found to be very difficult to use IT for this purpose. We therefore set out by concentrating on points that are directly connected to operation and management and points related to how knowledge should be stored and utilized.

2) Improved communication and information sharing (in company meetings, etc.)

We have shown that by using a projector to display the contents of a personal computer screen, one can deliver routine work reports and share information between experienced and inexperienced farm workers, including specific information about harmful insects or growing conditions, and offer expert advice.

2.2 Summary of demonstration

On the basis of fieldwork findings obtained after experiencing actual farm work for more than one month in total (**Figure 1**), we thought that it might be possible to support agricultural work with IT through the flow sequence shown in **Figure 2** (input → data storage → visualization → analysis → instruction). In this section, we describe the mechanism of this sequence and present a summary of the verification procedure.

We used Web applications and mobile phone applications to build prototypes of the four functions listed below, and we performed verification experiments with the cooperation of farming corporations at two locations in Japan (an outdoor vegetable farm in Miyazaki

Prefecture, and a rice paddy/dry field farm in Shiga Prefecture) to verify their effectiveness from the technical and business viewpoints.

Figure 1
Farm work experience.

1) Sales/planting (production) planning

Sales to customers and planting (production) planning for cultivated land can be performed together.

2) Operational planning/results management

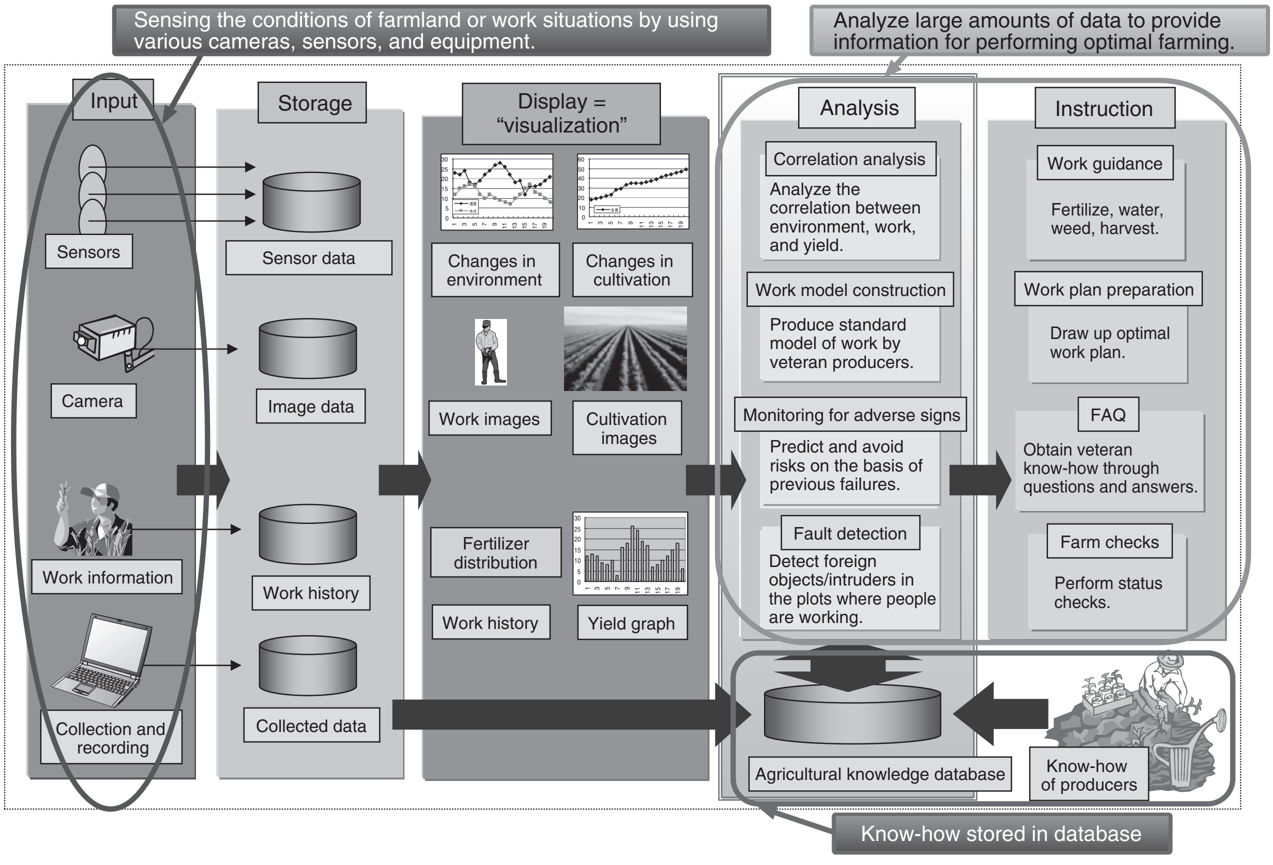
Progress management and operational checks can be performed on the basis of pre-planned on-site work and automatic collection of results.[5)]

3) Patrolling support

Reports and instructions can be easily and reliably issued by sharing on-site photographs and comments among all administrators and workers.

4) Cultivated land data management

Management of all sorts of data relating to cultivated land, including location, land rights, area, soil, and land characteristics can be



FAQ: Answers to frequently asked questions

Figure 2
IT mechanisms to support agricultural operations.

integrated.

These four functions are supported by two data management technologies listed below, which are based on technologies such as sensors (weather, soil, global positioning system [GPS]), networks (wireless local area network, third generation [3G]), and knowledge management.

1) Data storage
- Position and time information from mobile phones with GPS functions
- Weather/soil sensor data
- Image and audio data obtained by mobile phones (with digital camera and audio recorder applications)
- Noteworthy data extracted from the results of routine work
- Materials management data obtained using mobile phones with barcode reading functions

2) Data analysis
- Registering and updating virtual models
- Data mining

The above functions should eventually make it possible to add functions to address various different requests from on-site workers. In the future, we plan to construct a series of prototypes and subject them to verification trials. In particular, we intend to construct prototypes of two mechanisms and a database, as described below.

1) Planting simulation

A mechanism to support the drafting of optimal planting plans based on knowledge management and a cultivated land database.

2) Profit-loss calculations for each plot of land

Mobile phones with GPS functions are used to automate the collection of position and time data (which is sent to a server automatically by 3G transmission). This is used to implement a mechanism for performing profit-loss calculations for each plot of land on the basis of information such as data representing which people went where and for how long, which is used to calculate human resources costs that make up the bulk of indirect costs, and material expenses obtained by mobile phones with barcode reading functions.

3) Cultivated land records

A database of static data such as land rights and land areas, together with plot characteristics, soil analysis results, production histories, and the like. The managers of the farming corporations that cooperated with the verification trials responded very enthusiastically, saying that implementing these measures would change the face of Japanese agriculture. As a whole, this system is referred to as the "farm work management system" (provisional title).

2.3 Expansion into other fields

With the exception of "cultivated land data management," three out of the four functions mentioned in the previous section are not specific to agriculture but also have potential applications in various other fields (such as medicine/nursing and maintenance work), where technologies such as GPS activity sensing, Web-based mapping applications, and data mining are already being used. We are therefore working not only on vertical integration of these concepts, but also on horizontal expansion into other fields.

IT resources are said to have spread throughout the world. This can certainly be said of offices and facilities such as factories and research centers. However, for this sort of on-site work, new IT applications are likely to be incorporated into terminal equipment other than personal computers and mobile phones. Even a single food-related business in Japan, such as retail, eating-out, or food manufacturing, is an industry with sales of the order of 80 trillion yen, so there is enormous potential for global development in these fields or in other fields with a broader base than the 10 trillion yen or so of the IT industry to which we belong.

3. Affinity with Cloud computing

Before investigating the application of IT to the field of agriculture, we confirmed the following five universal values of Cloud computing:

- Reduction of initial costs
- Allocation of resources on demand without limit
- Maintenance and upgrades performed in the back-end
- Easy rapid development including collaboration with other systems in the Cloud
- More possibilities for global service development

As a specific service based on these values, we envisaged the mechanism shown in **Figure 3**, where a PDCA cycle is applied to agricultural work, which involves successively performing and obtaining feedback from the following actions:

Plan: Draw up production and operation plans.

Do: Gather work results (this involves performing the actual work on-site, though IT support cannot be provided for this).

Check: Perform progress management and patrol the cultivated plots.

Act: Make any necessary modifications to the plans.

With this workflow, basic sensing and knowledge management techniques[6),7)] are likely to be the main ones used to provide Cloud services.

3.1 Resources

As mentioned in the previous section, data is routinely collected. This data includes weather and soil data, GPS data, image data, worker observations, and data related to cultivated plots of land. The quantity is 5–10 megabytes per case per day. Since agricultural data has to be stored for 10–30 years according to a report by the National Agriculture and Food Research Organization[5)] and since between half a

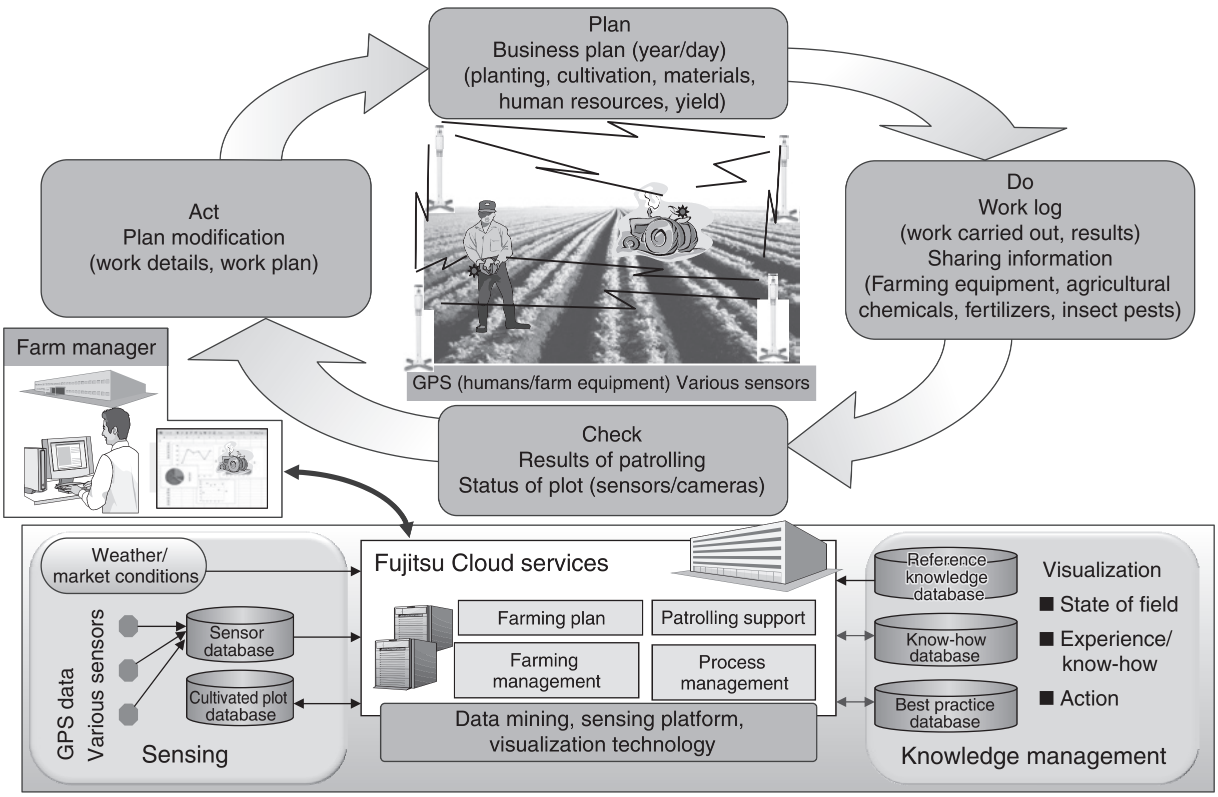


Figure 3
PDCA cycle and Cloud services in agriculture.

million and one million cases are targeted in the development of business, the total amount of data exceeds 100 petabytes (less than the medical field where the data storage requirements of personal health records are expected to reach 2 petabytes per patient).

To obtain advice and recommendations by analyzing this stored data, analysis engines such as data miners are operated on this large amount of data in the Cloud. Although it is not possible to calculate parameters such as the correct MIPS (million instructions per second) value, suitable central processing unit and input/output performances are required. In terms of performance, it is clear that highly efficient (high sustained performance) parallel computer technology or the like is necessary.

3.2 Maintenance

When IT systems are introduced into any new field, not just agriculture, frequent bug fixes and upgrades are needed. In Cloud computing, instead of an engineer having to visit an office to do this work, the maintenance work for hundreds of thousands or even millions of users can be done simply by amending and adding to the software on a single system in the Cloud center; this could solve many of the problems associated with maintenance. Moreover, in Cloud computing, there are no disparities in the software versions being used by different users, which leads to improved usability in addition to reduced maintenance problems.

3.3 System cooperation

Fujitsu's strengths lie not only in individual elemental technologies, but also in our ability to integrate various technologies together. Even from a global perspective, there are very few businesses that can combine skills in such diverse fields as sensors, mobile phones and other terminals, network services (security, authentication, multimedia), business applications, and back-end server storage. Indeed, businesses of this sort are tending to decline in western developed countries where they have become more specialized since the last century. However, companies such as Google are tending towards vertical integration. To promote the use of the Cloud services offered by Fujitsu, we should consider the need for tools that can reach individual users. In this sense, Fujitsu possesses a powerful arsenal for competing in Cloud services.

Since the initial prototype stage, the farm work management system used in the verification trials was aimed at providing total support for agricultural businesses by linking together the following three systems belonging to the Sales Unit, Farming, Forestry & Fishery Systems of Fujitsu Ltd., Fujitsu Kyushu Systems Ltd., and Fujitsu Hokkaido Systems Ltd.:

1) Business management system

System for performing financial analysis and filing tax reports with the support of tax counselors.

2) Production history system

Production history logging system that provides traceability records leading to food that is safer and more dependable.

3) Good Agricultural Practice operational support

System that efficiently manages safety and quality improvements in farm produce by supporting the operation of the Good Agricultural Practice farm work standard.

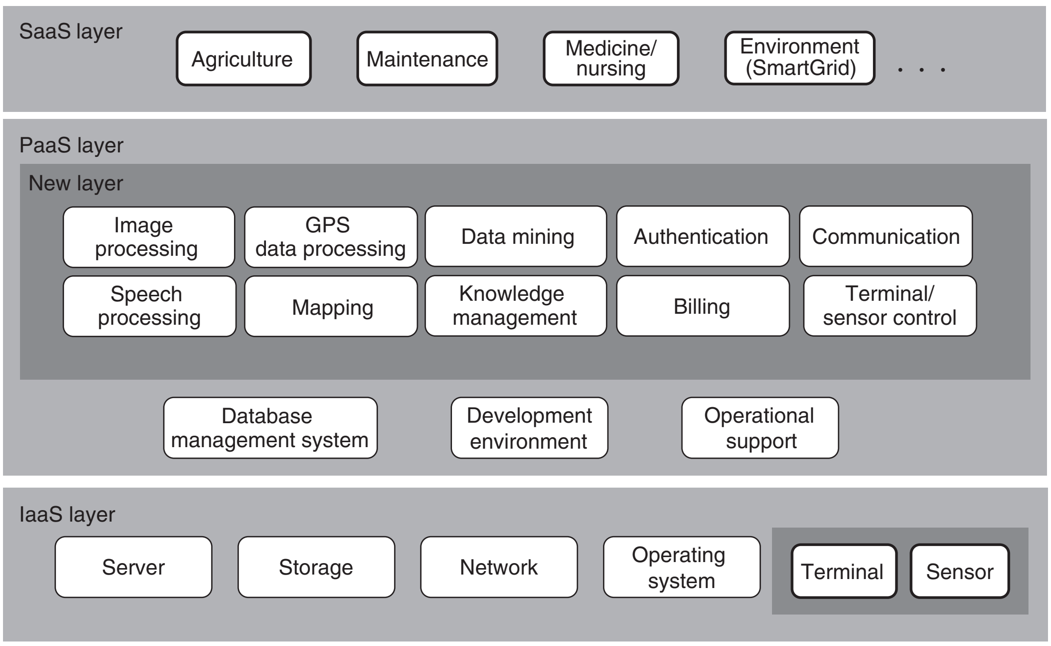
These systems have been utilized by many users such as JA (Japan Agricultural Cooperatives) and agricultural farming corporations since the client-server computing era. The migration of the business management system to software as a service (SaaS) was completed in the first half of 2009, and this service has now been launched on Fujitsu's Service Oriented Platform. Migration of the production history system to SaaS completed in the first half of 2010. In the future, we expect to tie together the cultivated land records and profit-loss calculations for each plot of land, and the planting simulations cited in the previous section.

In the next stage, we will need to link together the CRMate Customer Relationship Management solution, supply chain management solution, and Ub!Point and SS Tube for handling video information. These are not simply combined into a single system as a sort of mash-up, but are used to provide functions that become necessary when providing services suited to businesses. In other words, the field of agriculture is not just a production activity but also encompasses other forms of communication between people, such as sales and logistics. In the real world, various mechanisms are integrated together. Digital societies are projections of this sort of real world and should all be connected together. The field innovations and business process outsourcing promoted by Fujitsu from the outset are based on this sort of viewpoint. Using Cloud computing to flexibly link together a company's diverse systems is one of our guiding principles here at Fujitsu.

4. Proposed platform

We also have the role of making proposals for Fujitsu's Cloud computing platform. Mash-ups of the various systems cited in the previous section also require flexibility in the platform structure. Even when one is considering just one agricultural service application, the required functions include basic authentication and billing functions that can be shared with other fields such as GPS data processing and mapping systems. Other functions that should be shared with other fields are too numerous to mention, but include image/speech processing and data mining. These functions can probably be used not only in agriculture but also in any business where work needs to be done on the spot, such as medicine/nursing and maintenance work. Some examples are shown in **Figure 4**.

At present, in the verification trials we are using a system with a vertically integrated structure, but from the beginning of the prototype development we have focused on the fact that it is possible to develop horizontally at the platform-



IaaS: Infrastructure as a service

Figure 4
Proposed layer structure for Cloud services.

as-a-service (PaaS) layer and below.

In the future, in parallel with holding specific discussions for the construction of optimal platforms in a cross-cutting internal fashion, we also intend to ensure greater exposure of Fujitsu's elemental technologies that have remained buried until now.

5. Conclusion

Agriculture has traditionally been maintained by families and communities where the passing on and sharing of knowledge is regarded as very important. The accumulation and sharing of knowledge has resulted in better overall efficiency and productivity. Agriculture is the embodiment of a large amount of ancient knowledge. If the leverage effects of IT can be widely developed, then we should be able to bring about a further leap in agriculture. It goes without saying that Cloud computing can support this process. Indeed, one might say that the mechanism of Cloud computing is highly suited to the task of handing down human knowledge to later generations. However, as mentioned earlier, there is still a long way to go before IT can be applied to on-site work in fields such as agriculture and medicine/nursing. And as this paper shows, the regions where Fujitsu is currently engaged in business development do not cover the majority of real-world applications.

At Fujitsu, by using Cloud computing as an opening into fields where IT has yet to be applied, we have found that it is possible to establish new models for the application of IT. On the basis of these achievements, we will continue to develop tools for on-site working in other fields where IT has not yet been applied, including home medical care/nursing. In this way, we hope to contribute to developments not only in Japan but throughout the world.

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