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Prospective for Successful IT in Agriculture

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ABSTRACT

IT doubtlessly contributes much to agriculture and rural development. The roles can be summarized as;

1. **To activate rural areas and to provide more comfortable and safe rural life with equivalent services to those in urban areas, facilitating distance education, tele-medicine, remote public services, remote entertainment etc.**
2. **To initiate new agricultural and rural business such as e-commerce, real estate business for satellite offices, rural tourism and virtual corporation of small-scale farms.**
3. **To support policy-making and evaluation on optimal farm production, disaster management, effective agro-environmental resource management etc., providing tools such as GIS.**
4. **To improve farm management and farming technologies by efficient farm management, risk management, effective information or knowledge transfer etc., realizing competitive and sustainable farming with safe products.**
5. **To provide systems and tools to secure food traceability and reliability that has been an emerging issue concerning farm products since serious contamination such as BSE and chicken flu was detected.**
6. **To take an important and key role for industrialization of farming or farm business enterprise, combining the above roles.**

Key words **: case base, decision support system, distributed system, field data acquisition, grid technology, key roles of IT in agriculture, user interface**

I. INTRODUCTION

IT policy for agriculture and rural development began in the late 1980s in Japan but it was not successful for a long time. The policy gave higher priority to hardware than software, resulting in insufficient data resources and poor applications that were not useful enough to convince farmers of beneficial agriculture with IT. Poor rural network infrastructure and IT literacy doubled this failure. The latest statistics of MAFF (http:// www.maff.go.jp/ toukei/ sokuhou/ data/ pcikou2003/ pcikou2003.htm, December 2002) show that 50% of farm households own PCs but only 10% of them use the PCs for farming. This number is much lower than that of other industries. This fact clearly indicates that farmers are not convinced about beneficial agriculture with IT.

Looking at the present status in Japan, we can be

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aware of the existing issues that need to be solved in order to extend IT to agricultural domain. Agriculture stands on the very complex interaction between biological, climatic and geographical factors in addition to human economic activities. The information under such a complicated system is unpredictable, unstable, subjective, site-specific and reliant on empirical decisions given the inherent variability of biological phenomena. Agricultural information with these features is typically beyond the scope of the information science used in industrial information systems, and this has led to the failure of IT in agriculture. We should also consider how to easily collect field data. Though field data are the basis for farm decision supports, few people realize the necessity of supporting it, while developing several decision support programs that need such data. Poor network infrastructure in rural areas is also one of the obstacles for IT in agriculture because the Internet is an important factor in whatever information system we develop nowadays and it usually helps to reduce the cost of system development and maintenance. Another difficulty is lack of computer literacy in rural areas. Finally, we must convince farmers of the benefits of IT. The key factors to consider for IT in agriculture are itemized as:

1. How to adjust software to the special features of agricultural information
2. How to enrich digital contents
3. How to utilize the Internet, especially to reduce time and monetary costs
4. How to provide easy-to-use systems for computer literacy
5. How to convince farmers of the potential benefits of IT

In the following sections, several key technologies to solve these issues are introduced.

II. FIELD DATA ACQUISITION

Undoubtedly, digital data contents are most important when we develop agriculture information systems, as mentioned above. Actually, fundamental and widely used data such as market information, weather information, and agricultural material information are becoming available in the Internet through several services by governments, local governments, semi-governmental agencies, academic institutes, commercial sectors etc. and both the quality and quantity are advancing, though the dataís inflexible interface and associated charges render it unsuitable for general use, especially by end users.

In addition to the above-mentioned fundamental data, site-specific field data are definitely necessary when a farmer requires some site-specific decision support. For example, a growth model may require soil and fertilization information for accurate predictions. To obtain such information, the farmer has to record field data continuously for a considerably long period. In spite of the importance, providing tools for farmers to easily collect these data was often neglected. The following systems have recently been suggested to

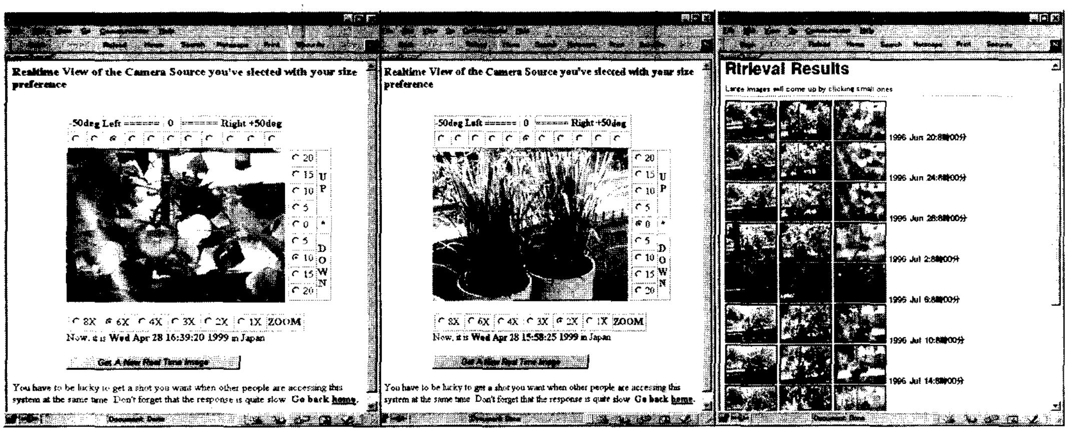

Fig. 1. A web-based camera server system, Field Eye. The user interface for the remote camera system (left and middle), the user interface for the automatically acquired image database system (right).

solve this problem.

To support recording of farm working journals, one of the most fundamental data collection methods from the fields, Kouno *et al.* (1998 and 2000) developed a system combined with a web camera and a meteorological robot. The web camera automatically collects crop images used to remotely analyze plant growth and condition. Application of the web camera (Fig. 1) to agriculture, originally suggested by Ninomiya *et al.* (1997), is now very common as reasonably cheap cameras and easy-to-use software became available.

Sugawara (2001) developed a mobile-phone-based farm working journal (Fig. 2, Sugawara 2001) to collect field data. The software is web-based and can upload farming data directly to a database from fields.

Otuka and Yamakawa (2003) and Otuka and Sugawara (2003) developed PDA-based field data collection systems combined with GPS (Global Positioning System). They record farming data on PDAs at fields combined with location data automatically measured by GPS and synchronize the data with PCs so that they can handle collected data, using a PC-based GIS application. Matsumoto and Machida (2002) and Kamiya and Machida (2002) utilized voice-recognition technologies to record farming data at fields. These system are easy to use and their mobility strongly support farmers *in situ* data collections

Recently, Fukatsu *et al.* (2003) developed a field monitoring system called FieldServer (Fig. 3, http://model.job.affrc.go.jp/FieldServer/FieldServerEn/default.htm). A FieldServer has ordinal sensors such as temperature, solar radiation, moisture, and soil temperature. It has very flexible interface and can optionally have several types of sensors such as a web camera, an infrared sensor, wind speed, wind direction and leaf wetness. In addition to its sensing functions, FieldServer can serve a wireless LAN access point so that each FieldServer can establish a wireless network with other FieldServers. This indicates that a whole region can be covered by the Internet accessible wireless hot spot, having several FieldServers deployed and just one link point to the Internet in the region (Fig. 4). The latest version of FieldServer is completely autonomous with no requirement for electric supply.

A FieldServer is remarkably inexpensive (<US$300) and as accurate as an expensive ordinal weather robot. Using its wireless LAN hotspot function, a ubiquitous rural area can be easily realized.

Field data acquisitions are becoming even more important because of the recent movement toward traceability of agricultural products whose information must be ideally trackable to original farming conditions, e.g. varieties, pesticide spray, harvest dates and producer names.

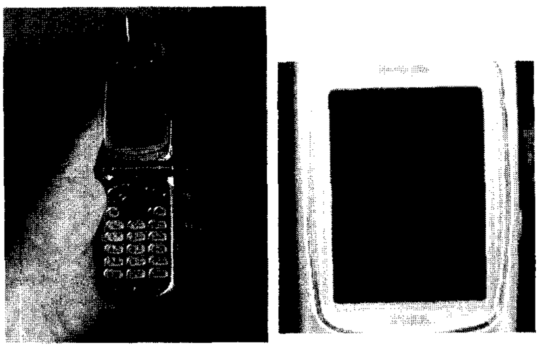

Fig. 2. Mobile-phone-based Web applications. Weather database access (left) and farm management diary (right).

III. CASE-BASED KNOWLEDGE MANAGEMENT AND DECISION SUPPORT

Fig. 3. FieldServer, wireless LAN autonomous field monitoring system.

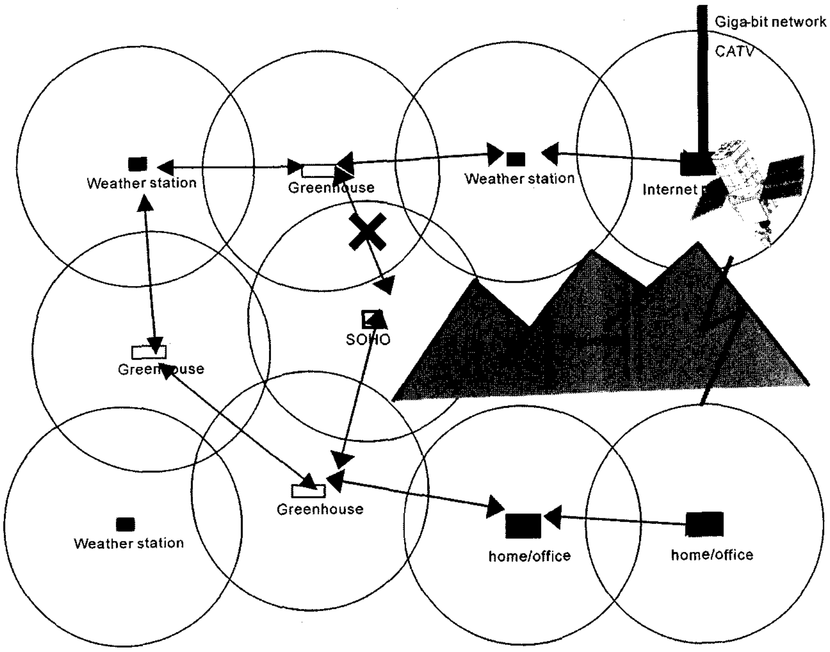

Fig. 4. Coverage of a region by FieldServers.

Natural science is based on a reductive approach. In this approach, the whole is separated into elements and each element is theoretically explained one by one. Then, the elements are compiled again to explain the whole. But in agriculture, where many factors interact complicatedly with each other, this approach sometimes fails. We have not yet succeeded in fully reductively explaining even the growth of rice, whereas empirical judgments by expert farmers are often sufficiently effective. The purpose of agricultural information systems is not to find out the truth, but to provide optimal decision support for farmers, and the reductive approach is not the only way. Case-bases provide one alternative approach.

A case-base is a kind of database that stores empirical cases and has a function to recommend relevant cases according to usersí decision-making queries. Our group (Otuka and Ninomiya, 1998, Otuka and Kitamurua, 2002) developed a prototype case base system, using a concept search engine that is based on latent semantic indexing (Deerwester, 1990). In other words, this is a search based on meaning. Using the system, one can retrieve cases without entering any keywords. The user can enter normal sentences as queries to the system and the system searches for recommended cases corresponding to the queries, based on the context or concept of the queries. This is a typical non-reductive approach and seems to be a very powerful way to transfer knowledge for farm decision support. The cases result from highly complicated farm factors and should contain much useful information. However, they are usually preserved in plain texts and are very difficult to properly retrieve with keyword-based searches because the contexts of the cases themselves provide useful information.

The case-based approach can be applied to several types of cases collected in many ways. E-mails exchanged in mailing-lists are good examples of cases. Images can be cases as well as ordinary texts. An example was suggested by Xin *et. al* (1998). In the system they developed, farmers request that extension services diagnose disease and pests by sending queries and images taken by digital cameras by e-mail, and extension services reply to these. These questions and answers (Q&A) and images are automatically stored as cases for a forth-coming automated Q&A system where the stored images and queries will be automatically matched with new queries and images to ascertain the proper answer.

IV. DISTRIBUTED SYSTEM AND GRID

4.1. Grid-based decision support

The most important advantage of the Internet is its use in information sharing between distributed resources. Such information sharing can greatly increase the amount of data available to users. Unfortunately, the will to share information in agricultural information systems is still weak and even at one site the same data sets can be ineffectively duplicated. However, new technologies to utilize the Internet make it possible for us to develop a distributed system called DataGrid for agriculture, which provides improved access to programs and effective utilization of available databases. The basic idea of DataGrid is acceptance of heterogeneity and autonomy of distributed resources.

In a Grid-based decision support system (Fig. 5), the network provides users with the necessary access to dynamically-linked programs and *in situ* data (Ninomiya, 2001). This approach provides the following benefits:

1. Multiple users can share a single executable module, avoiding duplication of software development and maintenance.
2. Multiple programs can share the same data set, avoiding duplicated data maintenance and management.
3. Data sets and programs are dynamically linked in the Internet, providing diverse functionality to users.
4. Programs and data sets are managed by their owners, facilitating updates and maintenance.
5. Developers have powerful sub model and data access components from which to assemble new programs.
6. Above features reduce cost of system development and maintenance.

4.2. Data Mediation and Broker

These benefits match the requirements of agricultural decision support system (DSS) for diverse data sets and multiple subprograms that we have to handle, but to realize this Grid-based DSS framework we face the major problem that similar kinds of data are stored in heterogeneous ways. For example, the weather databases published on the Internet differ in their logical structure, data management software and access method. Adapting each DSS to each database would result in inefficiency and redundancy as shown in Fig. 6.

We proposed the concept of data mediation as a solution for this issue, implementing the weather data mediation software MetBroker (Fig. 12, http://www.agmodel.org). MetBroker can absorb the differences between weather databases, providing a

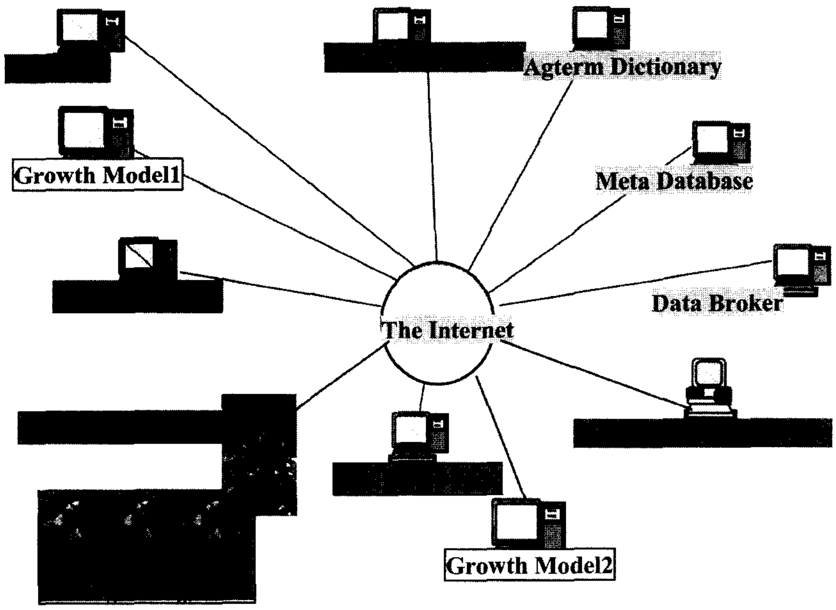

Fig. 5. Schematic diagram of a agricultural Gird system. See the text for the details.

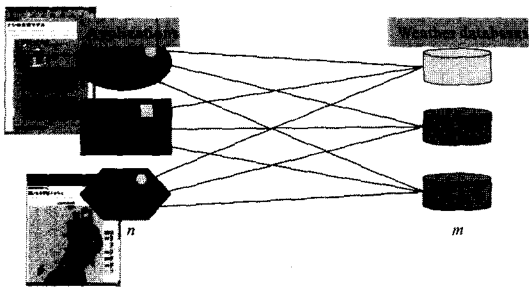

Fig. 6. If a weather data mediation program is not available, the number of code modules is proportional to n x m.

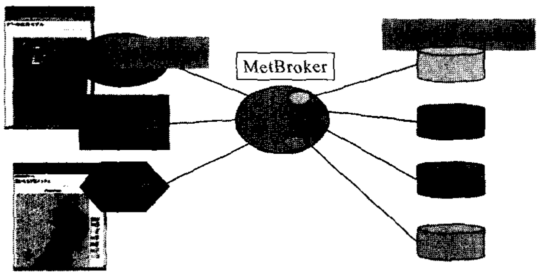

Fig. 7. A weather data mediation program, MetBroker. It decreases the number of code modules proportional to n+m.

consistent interface to client applications such as crop growth prediction models. MetBroker does not require any modification of the original databases (Fig. 7, Laurenson *et al.*, 2000 and 2002).

MetBroker provides applications with details of available data, receives requests from client applications specifying the elements, resolution and period required, queries remote databases and returns results to the client program. Requests can be either for a single station or the geographical area of interest. In the latter case, MetBroker returns results from multiple databases to the client, which is unprecedented functionality. The results of geographical requests can be used for spatially interpolation. MetBroker utilizes a powerful metadata structure to provide catalogues of available data to client applications, and identify which databases should service geographical requests..

MetBroker currently offers access to over 5000 stations in 14 databases in 7 countries. MetBrokerís original design makes it easy to add a new database, and MetBroker-linked DSS can use the new database immediately without any modification.

In addition to MetBroker, we have already developed SoilBroker, DEMBroker (Laurenson *et al.* 2002) and ChizuBroker. SoilBroker, DEMBroker and ChizuBroker mediate soil databases, digital elevation databases and map databases, respectively. These types of the databases are heterogeneously available over the Internet and important for agricultural decision support.

4.3. Applications of data brokers

Several applications that utilize the data brokers have been developed, mainly using the Java applet technology (Laurenson *et al.*, 2002). Fig. 8 shows crop models for Japanese pear and paddy rice. Both obtain weather data needed to predict growth through the mediation of MetBroker. It indicates that one can simulate how Japanese pear grows in Florida for example, combining the model with the weather data of Florida mediated by MetBroker without changing the model applets at all.

Fig. 9 shows a Java applet that displays weather data on the locations of observation stations over a map of the region. This is a typical application on a Grid system that dynamically combines different types of data. That is, weather data are mediated by MetBroker and map data in a different place from weather databases are mediated by ChizuBroker. This application also uses a function of MetBroker called spatial query that retrieves weather data from multiple databases which cover the same area.

Fig. 10 shows an applet that shows risk of extreme meteorological events by displaying circle charts of the event probabilities (Laurenson *et al.* 2001). This applet has a function to predict weather conditions of non-observation points by interpolation of observed data, combining with the data mediation by DEMBroker.

4.4. International collaboration among the Asian countries

We have plenty of knowledge and technologies that could be commonly shared among Asian countries, considering their similarities in terms of small farm scale and cropping systems. Therefore, international cooperation is inevitable and highly desirable, especially in Asian countries, having similar backgrounds in agriculture and rural development. Two major international activities for agricultural information technology in the Asia Pacific region started in 1998. One is the Asian Federation for Information Technology in Agriculture (AFITA; http://www.jsai.or.jp/afita/) and the other is the Agricultural

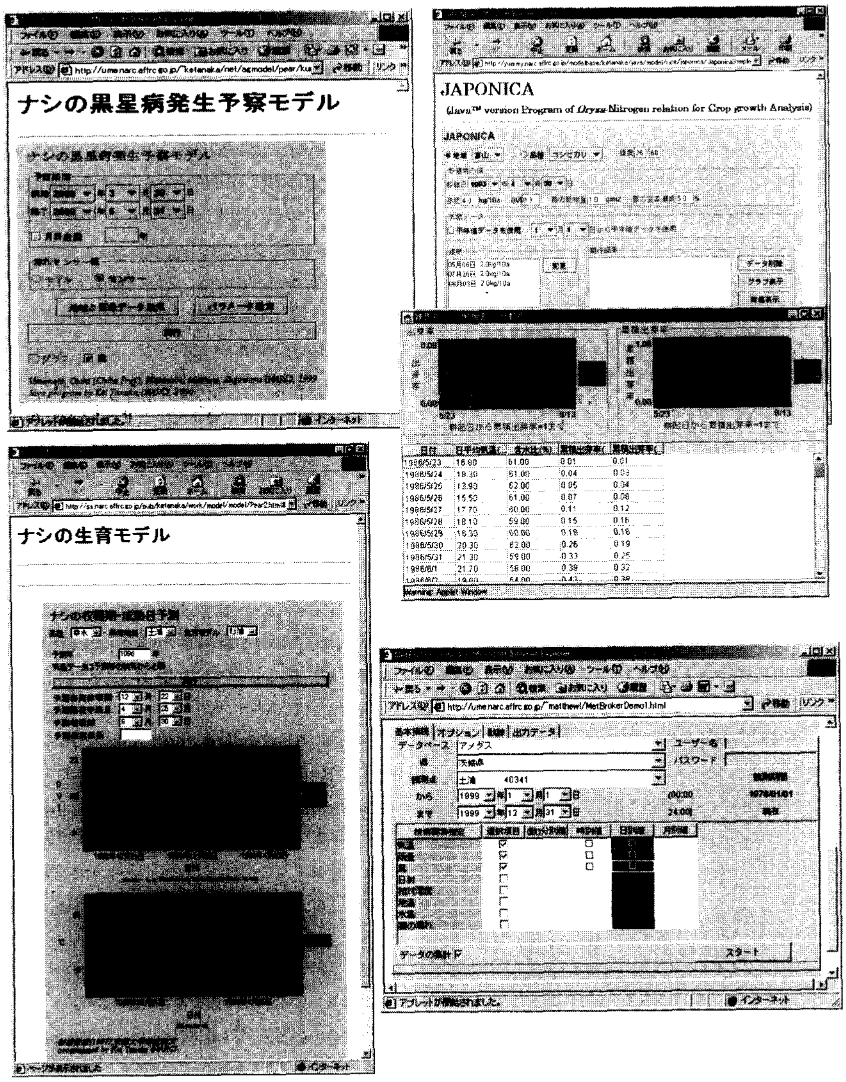

Fig. 8. Crop models as MetBroker applications such as a Japanese pear growth and disease prediction and a rice growth prediction.

Working Group of the Asia Pacific Advanced Network consortium (APAN/AG-WG; http://apan.net/).

AFITA and related activities

The AFITA holds an international conference every two years and has held three conferences already in Japan, Korea and China. The countries where local societies for IT in agriculture and rural development are available are the members of AFITA; these are China (Chinese Society for Agriculture Engineering, http://www.csae.org.cn, http://asscomp.caas.net.cn, National Engineering Research Center for Information Technology in Agriculture, http://www.nercita.org.cn/admin.asp), India (Indian Society of Agricultural Information Technology, http://www.insait.net/), Indonesia (Indonesian Society for Agricultural Information, e-mail: Ronnie S. Natawidjaja <ronnien@telkom.net>), Japan (Japanese Society of Agricultural Informatics, http://www.jsai.or.jp), Korea (Korean Society for Agricultural Informatics http://www.ksais.or.kr/), Taiwan (Taiwan Agricultural Information and Technology Association, e-mail:Ye-Nu Wan<ynwan@nchu.edu.tw>) and Thailand (Thai Agricultural Information Network, http://www.thaiag.net/

Fig. 9. MetBroker application which shows spatial weather data from a region over the map for a region. The same application can display weather of completely different databases. The left shows the data for the Wakayama prefecture from a prefectural local database and AMeDas for the region and the right shows the data for the Korean peninsula from the Seoul National University weather database and the Amedas DB of Japan. The map data is dynamically downloaded from a map server in US, using ChizuBroker.

thaiagEng.html) among the Asian countries. AFITA also accepts institutional participation from the countries without local societies as associated members; these are ICARD of Vietnam, MARDI of Malaysia, UPLA of Philippines, MAU of Mongolia, BAU and BOU of Bangladesh. AFITA has participants from international organizations such as FAO, CGIAR, APAARI etc.

APAN

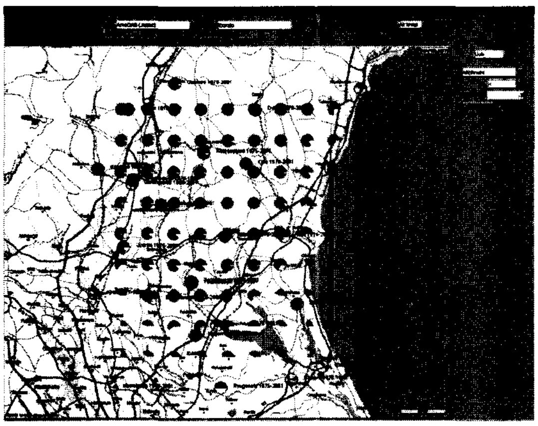

Fig. 10. MetBroker applet that displays extreme weather risk using circle charts over the location of observation points. It estimates the conditions of non-observed points as well, using mesh-interpolation. MetBroker, DEMBroker and ChizuBroker are jointly used to mediate three different types of databases.

The APAN is an NPO consortium that provides high performance Internet links among the Asia-Pacific countries for the research and educational purposes. The APAN also intermediates international research and educational collaborations that utilize the APAN infrastructure. The APAN agricultural working group (APAN/AG-WG) (http://agri-wg.jp.apan.net/) encourages use of the high performance network for agricultural research and its application. The APAN/AG-WG has undertaken several projects. The Bio-Mirror project to promote the mirroring of bio-sequence databases in the world (http://bio-mirror.jp.apan.net/) is a particularly successful project. Database mirroring of FAO/WEICENT and International Rice Research Institute (IRRI) located databases are also planned. Distance learning is a suitable application of the APAN high performance network as well. The availability of APAN's fast network infrastructure made videoconferencing possible (Raab, 1999).

Wild fire in tropical forests occurs unexpectedly and brings serious problems. Often it is quite difficult to detect it from land. The ANDES (http://www.affrc.go.jp/ANDES/) project purpose is to detect such wild fires, utilizing satellite images acquired by NASA and NOAA in the USA. These images are sent to a super computer in MAFFIN (Ministry of Agriculture, Forestry and Fishery Research Network System in Japan) via APAN where they are analyzed to extract information regarding fires in tropical forest areas in the Southeast Asian countries. The results of the analyses are sent through the APAN network to the countries where fire has been detected.

The international sharing of meteorological databases via MetBroker is also planned under APAN. Considering the Asian farming conditions mentioned above, we should be able to share many agricultural programs but the heterogeneity in the meteorological databases blocks it. This project will provide a fundamental broker system to solve the problem, applying MetBroker as a key technology. This idea can be extended to other types of databases (soil, crop, etc) as well. FieldServer introduced above is also becoming a target of a new project in APAN.

Multilingual information exchange

In spite of the importance of data sharing, the large diversity of languages and characters in the Asia region prevents us from the sharing. We often realize that we cannot even consult dictionaries because of unfamiliar characters. To overcome this obstacle, machine translation is highly expected. Actually the progress of the technologies is outstanding especially between similar languages. For example, Japanese-Korean translation and vice-versa is now rather practical. To apply this technology to agricultural and rural development, we must enrich dictionaries and ontology of the specific terms in the field.

Laurenson *et al.* (2002) developed a menu localization system based on their broker concept (Fig. 13). This system provides a multilingual menu term server that supplies an appropriate set to menu terms of a requested language by client applications. Once a set of menu terms in a language is ready, we do not need to duplicate or recompile the program for the language. In other words, once an application is developed to obtain menu terms from the server, the application can be automatically localized to all the languages available at the server.

Recently, a new APAN project on multilingual information exchange was initiated (http://ml-wg.cpe.ku.ac.th) to provide a tool to share the data resource in different languages. The first step is to develop multilingual dictionary of agricultural terminology, multilingual thesaurus and ontology by cooperating with the Agrovoc project of FAO. Because fully automated translation of full text is still quite challenging, the first target is to provide a function to share tabulated information in different languages. A team at Kasesaat University has already developed a prototype application of the function.

V. DISCUSSION

In this article, we first summarized the roles of IT in agricultural domain. Then, after we looked back the Japanís experience in IT for agriculture and clarified the issues that we needed to solve, we introduced new technologies that can give us the solutions for the issues, showing successful applications of the technologies.

We did not discuss much about IT literacy in this paper but this is also tremendously important. In addition to reinforcement of IT education and training, easy-to-use interface is a big challenge considering IT literacy. Regular PC interface with a keyboard is definitely unacceptable by a majority of farmers. Several technologies are now available to provide easy-to-use systems for those end users. For example, mobile phoneñbased interface is promising as one of the solutions for this issue. The coverage of mobile phones is expanding even in developing countries and the small number of keys makes it easy to use. Because farmers do not require complicated decision supports, its simple screen is usually acceptable. The 2^{nd} and 3^{rd} generation mobile phones provide seamless connectivity to the Internet and can substitute for regular PCs if there are applications suitable to the mobile phone interface. Actually, mobile phones are now used not only for data collection but also for *in situ* decision support in fields. For example, Laurenson *et al.* (2002) and Sasaki *et al.* (2002) developed mobile-phone based applications to access the weather database so that farmers can always check weather conditions in their fields. More practical applications such as a pesticide warning system have also been prototyped. Its easier interface than PC and mobility to fields have been welcome by farmers. Another issue is rural network infrastructure. Unfortunately, significant commercial competition cannot be expected in rural areas and the responsibility for dealing with this matter will fall on governments.

We also did not discuss a technology named data-mining in an analogy with mining gold from gigantic mountains. We have now a huge amount of data in agricultural production and experiments that have been recorded in the 100 years since modern agriculture started. These long-term data may be the source of critical information that gives us new knowledge in agricultural production. The data-mining technology seems to be promising to analyze such huge amounts of data and extract unknown facts.

Many people dream of agriculture empowered with IT. However, when they are asked what practical measures would empower agriculture in this way, most are at a loss to explain. It is mainly because there is no general answer to the question. Agriculture is typically site-specific, depending on climatic and soil conditions, cropping style, market requirements and so on. Therefore, it is the decision makers using IT who are best placed to adapt flexible technologies according to their individual situations (Laurenson and Ninomiya, 2002).

적 요

농업분야에서의 IT역할에 대한 요약과 함께, 일본의 경험을 살펴보는 한편 당면 현안의 파악, 그리고 정보기술 활용의 성공사례를 들어 문제해결 방안의 하나로 신기술을 소개하였다. IT 활용능력 여부는 성공적인 IT현장활용의 매우 중요한 요소로,. IT 관련 교육/훈련의 강화 외에, 사용이 용이한 인터페이스 여하는 IT활용력 제고의 커다란 도전이기도 하다. 기존의 자판형 PC 인터페이스는 대다수 농민들이 쉽게 받아들이기 어려운 면이 있는 것이 분명하다. 이러한 최종사용자들에게 사용이 보다 쉬운 컴퓨터시스템을 제공하기 위한 여러 가지 기술들이 현재 개발되어 있다. 예를 들어 휴대폰기반의 사용자 인터페이스는 이러한 문제에 대한 해결책의 하나로 매우 유망한 기술임에 틀림없다. 휴대폰 사용은 개도국에서도 점차 확대되고 있으며, 단 몇 개의 키만으로 쉽게 사용할 수 있는 장점이 있다. 농민들은 복잡한 의사결정지원을 필요로 하지 않기 때문에 휴대폰의 이러한 단순한 화면도 대개 충분한 기능을 구현할 수 있는 것이다. 제2, 3세대 휴대폰은 인터넷에 대한 무결성 접속을 제공하므로, 휴대폰인터페이스에 적합한 활용물을 개발한다면 기존 PC의 역할을 대신할 수도 있을 것이다. 실지로 현재 휴대폰은 자료수집 뿐만 아니라 포장에서의 현장 의사결정지원에 사용되고 있다. 예를 들어 로렌슨 등과 사사끼 등은 휴대폰기반 기상정보취득프로그램을 개발하여 농민이 항상 자신의 포장내 기상상태를 파악할 수 있게 되었다. 병충해예찰시스템과 같은 보다 실용적인 응용프로그램도 이미 초기모형이 개발되어 있다. PC보다 사용이 용이한 인터페이스와 포장에서의 기동성 등이 농민들에 의해 환영받고 있는 점이다. 또 다른 중요한 문제는 농촌의 미진한 네트워크 하부구조에 기인한다. 불행히도 농촌지역에서는 상업통신업자간 치열한 경쟁을 기대할 수 없기 때문에 이 문제는 결국 정부의 책임일 수 밖에 없다. 거대한 산맥에서 금을 채굴하는 것과 유사한 정보탐색이라는 기술도 매우 중요한 요소이다. 근대농업이 시작된 이래 약 한세기에 걸친 농업생산과 실험연구의 결과, 일본은 방대한 농업자료를 보유하고 있다. 이러한 장기자료는 농업생산에서의 신지식을 생산제공하는 데 필수적인 결정적인 정보원일지 모른다. 정보탐색 기술은 이러한 방대한 자료의 분석을 통한 미지의 사실을 추론하는 유망한 기술로 이용될 것이다. 많은 이들이 IT기술에 의해 농업이 힘을 얻기를 기대하고 있다. 그러나 어떠한 실용적인 IT대응책이 농업을 강화할 수 있느냐는 질문에 대한 답변에는 궁색할 수 밖에 없다. 이는 이러한 질문에 대한 보편적인 해답이 없기 때문이다. 농업은 전형적으로 기후와 토양조건, 작부양식, 시장요구도 등에 좌우되는 지역특이적 특성을 지닌다. 그러므로 이는 개별 여건에 알맞는 유연한 기술 적용 여부를 결정하는 IT활용시 의사결정자을 하는 사람의 몫이 될 것이다.

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