An IT system development framework utilizable without expert knowledge: MZ Platform

— Toward end user development in manufacturing industry —

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In recent years, manufacturing companies are being challenged to meet various social demands including short-term delivery, multiobjective production, quality assurance and traceability security. In order to meet these demands, keep and strengthen competitiveness, it is necessary for those companies to introduce IT. However, since it is often too expensive for small and medium sized enterprises to develop, operate and maintain IT systems, they cannot introduce them. We have developed an IT system development framework "MZ Platform" which enables manufacturing industry workers to construct and operate IT systems without professional IT knowledge, in order to encourage manufacturing companies to introduce IT systems. We describe our research and development approach and dissemination activities, and discuss effects of MZ Platform.

Keywords : Component-based development, software component, manufacturing industry, IT system, end-user development

1 Introduction

Recently, manufacturing industrial environment is becoming more and more competitive. Manufacturing companies are being challenged to meet increasing demands including short-term delivery, multiobjective production, quality assurance and traceability security. It is widely recognized that systemization of workflow and digitization of documents by introducing information technology (IT) is effective in meeting those demands, and many kinds of software applications are currently available for engineering design and manufacturing such as CAD systems. However, especially for small and medium sized enterprises (SMEs), the development, operation and maintenance costs of IT systems are too high, and it is difficult to assign a worker with sufficient knowledge and experience of managing IT systems. As a result, it is often the case that a manufacturing company fails to introduce and make use of IT systems.

This research aims to encourage manufacturing companies to introduce IT systems. In order to achieve this aim, we have developed and diffused an IT system development framework for end user development,[1] called "MZ Platform," which enables manufacturing industry workers to construct and operate IT systems without professional IT knowledge. That is, this research involves two kinds of activities: one is technological development of an IT system development tool for non-professional programmers, the other is diffusion of it with establishment of an end user support organization.

2 Technological development

2.1 Target of technological development

"MZ Platform" is a component-based IT system development tool which enables a worker to build up an IT system without writing source code. Conventionally, in order to build up an IT system, it is necessary for a worker to learn a programming language and write source code by using it. However, it is quite difficult for a worker without sufficient IT knowledge to do so. Therefore, we have employed a component-based development method[2] in order to remove those difficulties.

A component-based development method is a way of building up a whole IT system by combining small separated off-the-shelf programs named software components. This is well known as an extension of object oriented development in the field of software engineering. Commercial component-based development tools, such as Microsoft Visual Studio,[3] are currently available.

However, though these tools provide a function of making up a basic structure of a whole IT system by combining components, the programmer has to write source code for detailed functions of each component. That is, these conventional tools are for users with considerable knowledge and experience of programming, and are too difficult for a user with insufficient IT knowledge to use. Therefore, we have established our research objective of developing a full component-based IT system development tool which

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completely eliminates source code writing.

2.2 Technological issues and development approach

This technological development has two major issues as below.

(1) Proof of usefulness of full component-based development

It is necessary to prove that it is possible and useful to build up an IT system for practical use in production lines of a manufacturing company, in accordance with the manner of full component-based development which eliminates source code writing for detailed functions of software. Since theoretical proof is impossible, we illustrate the usefulness by case studies.

(2) Preparation of a set of components

It is necessary to prepare a set of components with sufficient variety and generality which improves efficiency of development of an IT system satisfying various requirements of manufacturing companies. It is most important to decide classes and functional granularities of components.

In order to work on these issues, we conducted our research work through development of practical IT systems for manufacturing companies (Fig. 1). We collaborated with several manufacturing SMEs to build up practical IT systems, such as a production management system, for each of them, and then illustrated the usefulness of our full-component based development method by these case studies. In addition, we studied what kinds of components are necessary through the case studies and decided classes and functional granularities of components.

We conducted our research work in accordance with the following steps.

(i) Hearing to each manufacturing company
(ii) Workflow analysis and establishment of requirements of the IT system for the company
(iii) Making up components necessary for the IT system
(iv) Development of the IT system
(v) Evaluating the IT system and extracting standard functions
(vi) Reorganizing the equivalent functions of the IT system by combining the standard functions
(vii) Making up components based on the classes of the standard functions

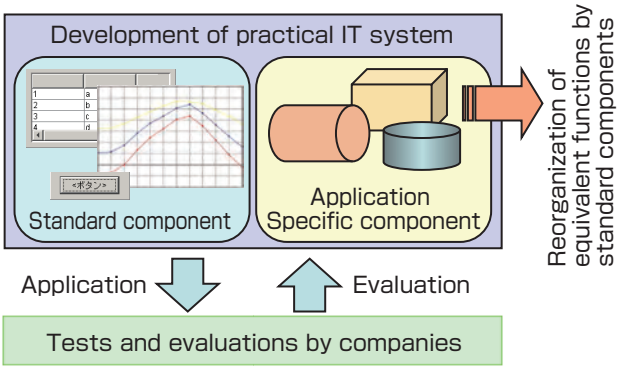

Fig. 1 Research work through development of practical IT systems

Within the above steps, steps (i) to (iv) are research activities associated to “Proof of usefulness of full component-based development,” and (v) to (vii) are those associated with “Preparation of a set of components.” We refer to “a component based on the classes of the standard functions” as “a standard component” in the following part of this paper.

2.2.1 Development of practical IT systems for manufacturing SMEs

We have developed practical IT systems for manufacturing SMEs, including a process management system to monitor progress of processes and a technical knowledge management system to search and show necessary technical data. We have conducted the development in order to illustrate the usefulness of full component-based development, and to investigate the essential and general problems faced by manufacturing SMEs. Before developing the IT system, we conducted a hearing to the manufacturing company to decide its specification. Some of company workers’ opinions and requirements were not necessary or appropriate to reduce load of workers. For example, too much data input work might be necessary to operate the IT system they required. However, we accepted their opinions and requirements as much as possible, because we thought it was necessary and important to understand their issues and problems accurately.

We developed each IT system according to the following steps.

(i) Identifying necessary functions
(ii) Breaking down each function into sub-functions recursively until we obtained elemental functions which cannot be decomposed properly
(iii) Making up components for each elemental function
(iv) Building up an IT system by combining those components

During the development, we kept in close contact with the companies, and repeated tests, evaluations and improvement of IT systems every few months.

Through the experience of developing IT systems for practical use in the full component-based method, we found that this method is useful for improving IT systems. An IT system built up by the full component-based method consists of sub-functions highly independent of each other. Therefore, when

it is demanded to improve the IT system, since it is easy to focus on and identify what should be modified, it is possible to reduce work load for the improvement. This is quite suitable for developing companies' work management systems which have to be adapted to changes of business forms. This also means that classification of component functions is very important for making the best use of the full component-based development method.

We found two major essential issues for manufacturing SMEs, through these IT system development case studies.

One is an issue of workflow analysis to find out problems in each company and work out solutions. When a worker conducts workflow analysis, he/she usually claims problems and requirements from his/her own viewpoint. It is often the case that some requirements are in conflict with others. For example, a manager often requires production data and results of data analysis in detail. However, in order to obtain detailed information, workers have to input a lot of data. It comes into conflict with workers' requirement of reducing work load. In order to improve working process by introducing IT, it is important to estimate costs of introducing and operating an IT system, and effectiveness of the IT system in improving the working process, and to make the aim and the objective of introducing the IT system clear, and then to establish a consensus among all the stakeholders including managers, workers and IT system developers. We show several examples of companies in Chapter 4. They have succeeded in introducing IT systems mainly because they made their targets clear.

The other is an issue of information management in an integrated manner. We have developed various IT systems such as a process management system and a technical information management system. Essentially, they are used to manage a lot of data separately recorded on paper or electrical documents in an integrated manner, to resolve inconsistency among those data, and to reduce work load.

The above knowledge obtained from the experiences were very useful for deciding classes of the standard components and to guide companies in their introducing IT systems.

2.2.2 Preparation of standard components

As described in the previous section, we have developed the IT systems in order to understand the essential problems faced by manufacturing SMEs and to find out necessary functions for improving their work by introducing IT systems. Therefore, components used for the development were made based on the necessary functions for each company, and some of them were not applicable to other companies. We reinvestigated the means of executing necessary functions and reorganized functions equivalent to the developed IT systems by combining the standard and highly generic functions, and then we made up a set of standard components with sufficient variety and generality which improves efficiency of development of an IT system satisfying various requirements of manufacturing companies.

We conducted the above work by dividing and generalizing the component functions for specific companies. Those components have elemental functions which cannot be divided anymore as processes in each company's workflow. However, those elemental functions can be still divided in terms of software program processes. We divided those elemental functions and decided on standard functions applicable to the development of IT systems for various companies.

On the other hand, we developed a new component with generic functions for similar functions used in various IT systems. For example, many companies record their various data in the form of tables. Since the data table structures such as data items and properties are different in each company, it is impossible to use one company's data table in another company. This means that it is impossible to use one specific data table component for another company. However, if the data table component has a function to change its data table structure, it can be used for various IT systems.

Fig. 2 shows an example of the preparation of standard

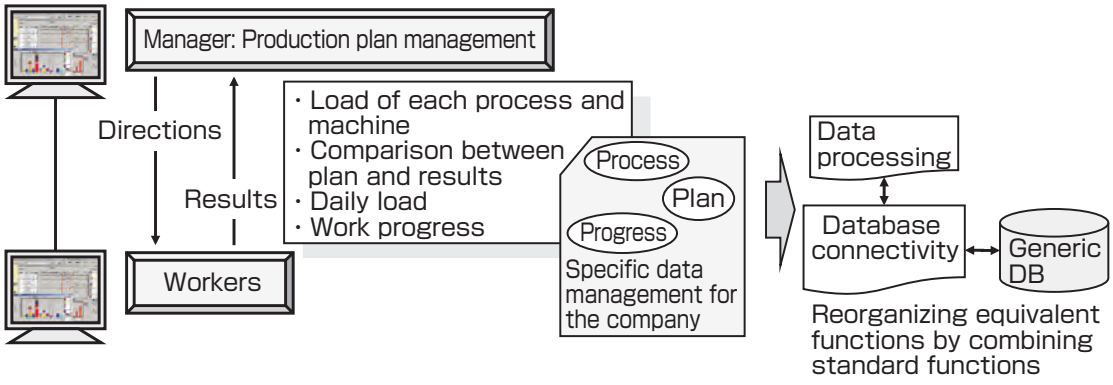

Fig. 2 Example of preparation of standard components in a process management system

components for a data management function of a process management system developed for one manufacturing company. This company did not have an IT system and managed their manufacturing data in the form of paper documents. Therefore, the manager could not follow manufacturing process progresses in real time. This process management system was developed to solve this kind of problem. In this development, we made a specific component which stored and aggregated data necessary for management. We reinvestigated the component function and divided the component into two separate components with data storing functions and data aggregating functions. Furthermore, we decided to use generic database software to store data, developed a new standard component to connect with databases, and used it for data storing. As for data aggregating functions, we developed a standard component with generic data processing functions including statistical and table calculations and replaced the company specific component with the standard one.

As shown in this example, MZ Platform does not always provide all the necessary functions for itself. We regard it as important to connect MZ Platform with other software systems and utilize their useful functions. It is also useful in interacting with existing systems such as an accounting system thereby building up a total information management system in a company.

Finally, we prepared about 180 kinds of standard components which collectively provided most of the necessary functions of IT systems for manufacturing SMEs. After that, we added new components continually in response to users' requests including demand for Web functions. Currently, MZ Platform has more than 200 kinds of standard components.

2.3 Architecture and functions of MZ Platform

MZ Platform consists of the application builder which provides functions for development and execution of an IT system, the application loader which executes a developed IT system, and standard components for IT system development. All of them are implemented in Java language.[4]

2.3.1 Application builder

The application builder provides a user interface for IT system development and test run. In comparison with conventional source code writing, a user builds up an IT system easily by combining components on the application builder's graphic user interface (GUI). Fig. 3 shows the process of IT system development on the application builder.

A user selects necessary components from a popup menu and describes execution processes in the form of a chart expressing connections between components. Display layout of GUI components is arranged on another display layout window. The user can easily add and modify a function of the IT system by adding, removing, connecting and disconnecting components.

Ease of modification of IT system functions is one of the advantages of MZ Platform for adapting an IT system to continual work improvement. Conventionally, it is difficult to modify a once developed IT system, and its modification is very expensive. Therefore, it is often difficult to conduct work improvement which requires IT system modification. That is, it is often the case that the workflow is fixed by introducing an IT system and that it becomes impossible to improve work anymore. MZ Platform avoids this kind of problem and enables continual work improvement.

2.3.2 Application loader

The application loader is a tool for executing a developed IT system. Fig. 4 shows the relationship between the application builder and the application loader.

2.3.3 Standard components

MZ Platform has currently more than 200 standard components for IT system development of manufacturing companies. Table 1 shows an outline of MZ Platform

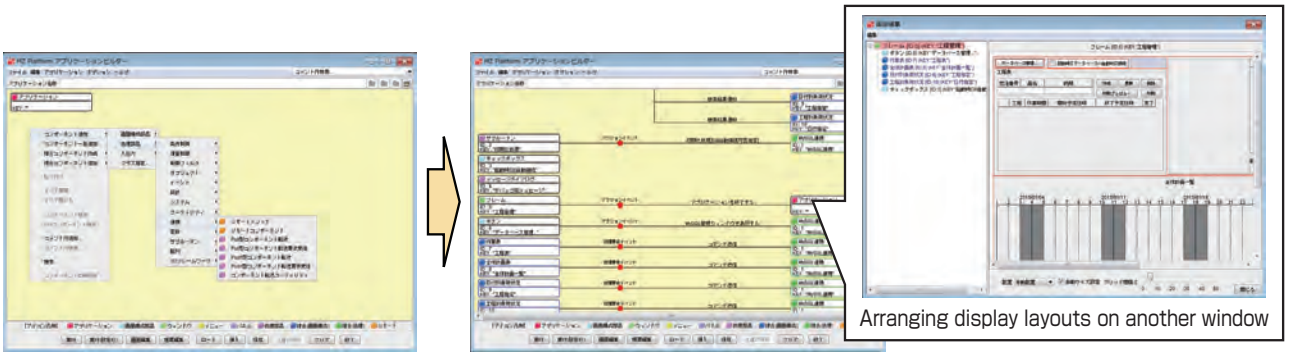

Fig. 3 IT system development on the application builder

Table 1. MZ Platform standard components

Classification		Explanation	Components
GUI	Operation	For user operations from GUI such as button click, text input and data display	Frame, Dialog, Button, Text field, Label, Image viewer, Menu bar, Tool bar, Table, Tree etc.
	Chart	For displaying table data in the form of various graphs	Bar chart, Line chart, Area chart, Plot chart, Pie chart, Gantt chart, Pareto chart etc.
Process		For data processing	Calculation, Logical operation, Table data processing, Function, Subroutine, External program interface etc.
IO		For printing and data input/output with external data sources including files and databases	Paper, Database access, Excel file access, CSV file reader/writer, Image file reader/writer, Serial port connector etc.

standard components.

In addition to the standard components, a user can create his/her own component by Java programming and use it for his/her own IT system. MZ Platform also provides documents, template files and sample application files for a user with programming knowledge to make a new component.

2.3.4 Evaluation of MZ Platform

We conducted evaluation of MZ Platform from 2004 to 2005 in order to quantitatively estimate the effectiveness of MZ Platform in reducing work load of IT system development. We evaluated MZ Platform from two viewpoints: one is the ease to learn how to use MZ Platform, the other is the time reduction of programming.

(1) Ease to learn how to use MZ Platform

We evaluated the ease to learn by comparing the learning time period with other programming language. We asked several professional programmers to learn how to use MZ Platform. Then, we compared the learning time period with how long they had taken to learn a conventional programming language.

We obtained the result that they were able to learn MZ Platform in no greater than half of the time for learning MFC/C++[5] or Java.

(2) Time reduction of programming by using MZ Platform

We developed IT systems for practical use for several manufacturing SMEs by using MZ Platform. Then, for each developed IT system, we asked a professional programmer to estimate how long it took to develop an equivalent IT system by using a conventional programming language. Table 2 shows the results of comparison of IT system development work load of MZ Platform with a conventional programming language.

In some of above cases, the worker who made the IT system by using MZ Platform is different from the professional programmer who estimated the working time by using a conventional language. Additionally, since the working time was estimated roughly, the comparison is not accurate numerically. However, it is enough to show the effectiveness of MZ Platform in reducing time of programming.

3 Diffusion of MZ Platform

In order to achieve our research aim of “end user development for manufacturing SMEs,” in addition to the development of MZ Platform, it is necessary to disseminate how to develop and introduce IT systems, to educate workers in utilizing MZ Platform, and to establish an end user support organization for SMEs. Therefore, we worked on diffusion of MZ Platform as below.

(1) Dissemination seminars

We have held dissemination seminars at AIST regional bases,

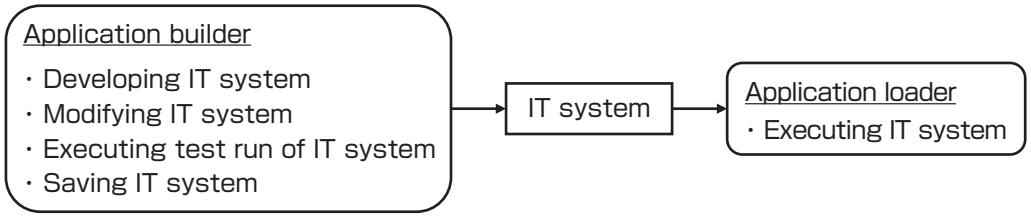

Fig. 4 Relationship between the application builder and the application loader

Table 2. Comparison of IT system development work load

Company	IT system	Working time	Comparison with a conventional programming language
Company union (Nagano)	Process management between companies	30 man-days	Less than 1/4
Cutting (Osaka)	Technical information management	3 man-days	Less than 1/10
	Quality check	10 man-days	Less than 1/3
Sheet metal working (Nagano)	Process design support	7 man-days	Less than 1/4
Press working (Nagano)	Production and document management	30 man-days	Less than 1/10
Injection molding (Oita)	Production plan and result management	45 man-days	Less than 1/3
Metal mold (Tokyo)	Progress management	30 man-days	Less than 1/4
Grinding (Fukuoka)	Order, process and quality management	25 man-days	Less than 1/3

prefectural research institutes and industrial associations all over Japan including 44 prefectures. At the seminars, we introduced functions of MZ Platform and case studies at manufacturing SMEs.

(2) MZ Platform consortium

We established "MZ Platform Consortium" as one of AIST consortia in 2004. We delivered MZ Platform to the members, held training courses and answered technical questions from the members via electrical mail. There were corporative and individual memberships. Membership fees were 1000 yen a year.

MZ Platform consortium closed at the end of June, 2014. Currently, MZ Platform is delivered to registered users by free download. We had 456 registered corporative and individual users in total at the end of December, 2014.

(3) Establishment of an end user support organization

We have established an end user support organization consisting of prefectural research institutes for regional consultation about IT system development. In addition, in accordance with the AIST technical training program, we accept company workers and educate them to build up their own IT systems. Furthermore, since it is necessary to make use of MZ Platform in business for lasting diffusion and user support, we work on making commercial license contracts of MZ Platform with software vendors.

Fig. 5 shows an overview of the MZ Platform support organization. A prefectural research institute primarily gives advice to manufacturing SMEs. A software vendor onerously gives information equipment and services such as designing databases. An AIST regional research base manages those activities. The Advanced Manufacturing Research Institute educates and trains persons in charge.

We do not always develop and introduce an IT system in accordance with the support organization shown in Fig. 5. In some cases, no software vendor joins since the SME decides to develop its IT system for itself.

When a software vendor does not have knowledge about MZ Platform, we usually propose that it joins a case study to

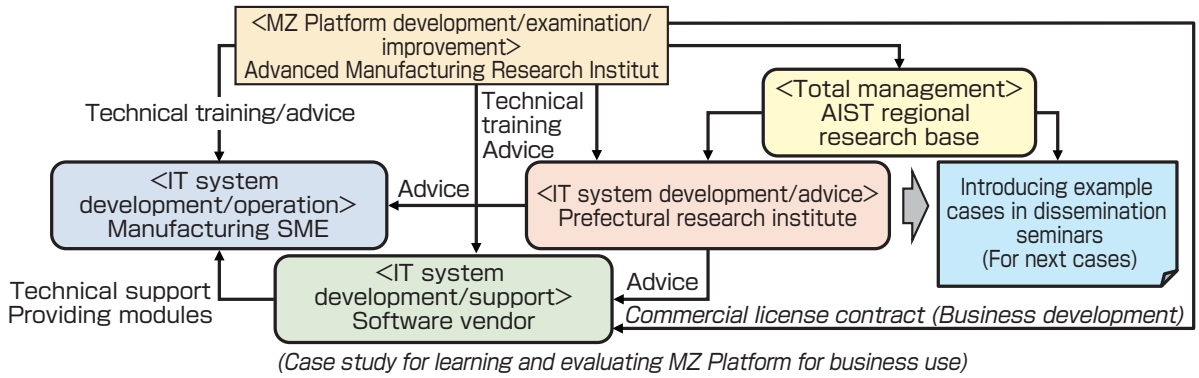

Fig. 5 MZ Platform support organization

evaluate whether MZ Platform is promising for its business. When it decides to use MZ Platform for its business, we arrange that it makes a commercial license contract with AIST to develop MZ Platform business.

4 Case studies

We introduce 3 case studies of IT system development in manufacturing SMEs using MZ Platform.

4.1 Production plan and result management system of an injection molding company (Oita)

Ohkawa Mould Designs & Engineering, an injection molding company in Oita Prefecture, has developed a production plan and result management system with the support of the Oita Industrial Research Institute. In this company, production plans and results were written conventionally on paper or white boards by hand. Therefore, states of production were checked every half-day at most and troubles due to miswriting were inevitable. The company developed an IT system to digitize information about production plans and results, thereby managed delivery precisely by checking production states every one hour, and reduced working time by 20 % on average. The company got a special award for IT management from the Kyushu Bureau of Economy, Trade and Industry for this IT system development in 2007. Furthermore, the success of this IT system development led to the pilot project of IT system development for SMEs[6] conducted by Oita Prefecture from fiscal year 2008 to 2010.

Fig. 6 shows an overview of the production plan and result management system. It uses conventional excel files to make and view production plans. Based on the production plans, working plans are made and working directions are issued. Production results are entered via handy terminals with barcodes, and then all the information is automatically stored in a database.

This IT system development process consists of 4 stages as written below. Time period for each stage is written in parentheses.

(1) Preparation stage (one month)
- Organization of a IT system development team
- Determination of the target of digitization
- Assignment of work to each member of the IT system development team

(2) First stage (three months)
- Analysis of the workflow
- Design of a new workflow with the IT system
- Design of the IT system

(3) Second stage (two months)
- Programming (making the MZ Platform application)
- Hardware selection

(4) Third stage (two months)
- Trial and revision

It was very important to clarify the target and objective of the IT system development, and to make responsibility of each member clear at the preparation stage. Furthermore, the Oita Industrial Research Institute played an important role in the management as well as construction of the IT system.

Company workers sometimes avoid to say their opinions frankly to their seniors or bosses. This might often cause failures in sharing problems and, as a result, in developing the IT system. The researcher of the Oita Industrial Research Institute gave impartial opinions, enabling workers to discuss frankly, and thus avoided such kind of failures.

4.2 Order, production and stock management system of a surface modification company (Nagasaki)

Shinto Industrial, a surface modification company in Nagasaki Prefecture, has developed an order, production and stock management system with the support of a software

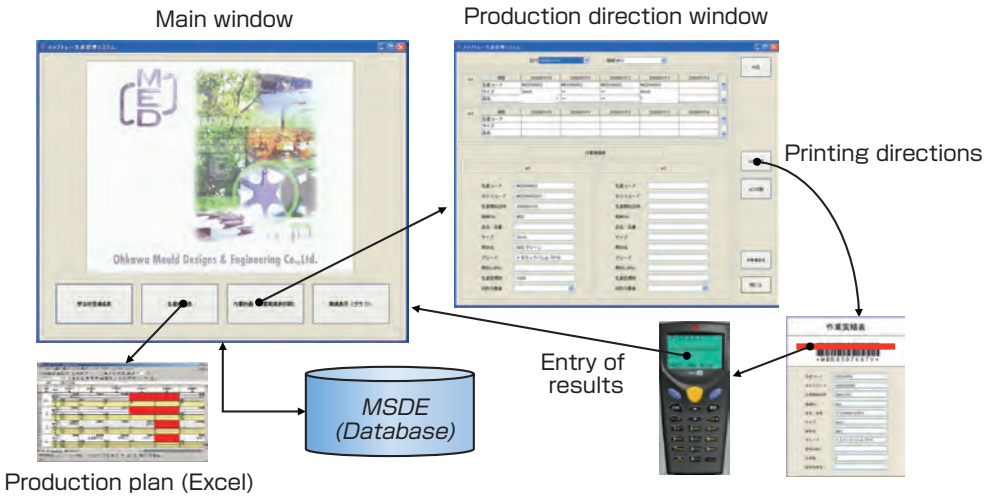

Fig. 6 The production plan and result management system (provided by Oita Industrial Research Institute)

Table 3. Tasks about the order, production and stock management system development

(1)	Creating the workflow and listing paper documents	Shinto Industrial
(2)	Determining the target of digitization	Cooperation
(3)	Design of the database	Cooperation
(4)	Design of the graphic user interface	Cooperation
(5)	Programming (making the MZ Platform application)	Software vendor
(6)	Test run	Cooperation
(7)	Operation of the developed system and further development	Shinto Industrial

vendor. This company had planned to digitize paper documents, estimate costs correctly by managing all the information in an integrated manner, and improve production efficiency. However, the plan was suspended because a suitable IT system development tool was not available. The company found MZ Platform and began to develop an IT system by using it. Fig. 7 shows the architecture of the IT system.

This IT system enabled the company to obtain the data about production and working ratio of equipment and analyze those data for improving efficiency. In 2009, for this IT system development, the company got a special award for IT management from the Kyushu Bureau of Economy, Trade and Industry and was certified as a practical IT management company by the Ministry of Economy, Trade and Industry.

In this case study, it was very important that the company and the software vendor shared work appropriately. Table 3 shows tasks involved in the order, production and stock management system development. They clearly divided the tasks into what the company had to do by itself and what should be done with professional IT knowledge of the software vendor, and then carried out the tasks efficiently. In the end, the company became able to operate, manage, and maintain the developed IT system for itself.

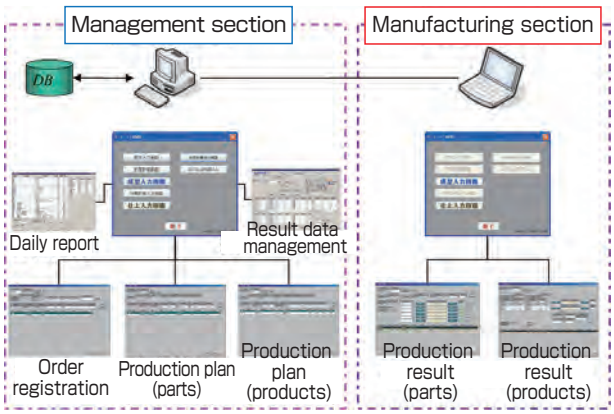

Fig. 7 The order, production and stock management system (provided by Shinto Industrial)

4.3 Order and progress management system of a metal mold company (Saga)

Shotoku Zerotec, a metal mold company in Saga Prefecture, has developed an order and progress management system with the support of the Industrial Technology Center of Saga and a software vendor. Though this company had introduced a package software system, it was hard to input daily working data correctly. Therefore, in order to input daily working data easily and correctly, the company developed an IT system with a real time record input function using barcodes. Figure 8 shows its overview.

Barcodes are printed on all the workers' name plates, machine tools and working directions. A worker can input all the data only by reading the barcodes by a barcode reader, and the input time is automatically recorded. By this IT system development, the company got a special award for IT management from the Kyushu Bureau of Economy, Trade and Industry in 2008, and was certified as a practical IT management company by the Ministry of Economy, Trade and Industry in 2010.

It is notable, in this case study, that the company utilizes the collected data for improving manufacturing processes by calculating the cost of each process correctly. Fig. 9 shows an example of the improvement of a manufacturing process.

The company calculated the cost of each manufacturing process for one product and found that the cost of only one process exceeded the price of the product. Then, the

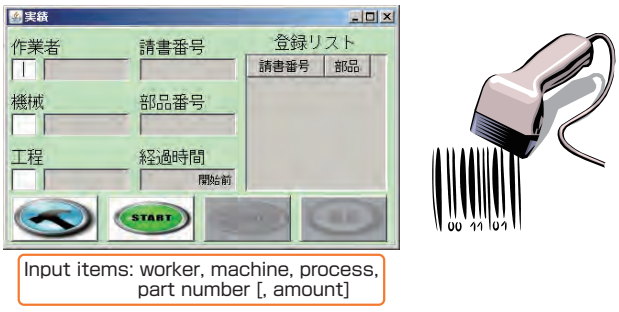

Fig. 8 The real time record input function using bar codes (provided by Shotoku Zerotec)

company improved the manufacturing process and succeeded in making a profit. It is important that the company made workers recognize the problem. The workers already knew that moment stops occurred. However, they did not associate that to the cost of the manufacturing process. The workers became aware of the costs as numerical data, recognized the problem, and then solved it.

4.4 Effectiveness of end user development and MZ Platform

As shown in the above case studies, those companies made the target and objective of IT system development clear at the early stages of development, and it led to their success. They were able to make the target and objective clear, because they worked on programming for themselves with the support of the prefectural research institute researchers and the software vendor programmers.

Manufacturing companies often fail to develop IT systems, especially in the case of outside order, because the manufacturing companies cannot communicate with the computer programmers very well. There exists difficulties in communication between a manufacturing company without IT knowledge and a computer programmer without manufacturing knowledge. If a manufacturing company worker becomes able to do programming, even though he/she does not have professional IT knowledge, he/she learns a way or manner of developing an IT system and becomes able to think about its target and how to make it. This kind of experience of programming and knowledge are useful for collaborating with computer programmers as well as for the company's own system development. This is typically shown in the case study of Shinto Industrial described in Subchapter 4.2.

When end user development is mentioned, merit of the user's own development is often described. However, we claim that it is much more effectiveness when collaboration between end users and professionals is encouraged through end users working on programming. The case studies described in this chapter illustrate that MZ Platform is an effective tool for promoting end user development.

5 Conclusion

"We had no way to realize our ideas for improving our working efficiency. However, we now have MZ Platform. We think about reducing our work load and improving our work every day, and realize our ideas as an IT system by using it."

This is a comment from a user in a manufacturing company. At the beginning of our research, we intended only technological contribution to reduce work load about programming. Bringing out individual workers ability for improving their work by providing an easy-to-use tool to realize their ideas goes far beyond our intentions. We consider it as the greatest effect of MZ Platform.

In this research, we worked on diffusion of MZ Platform very much, as a result of reviewing our activities at early stages of research. When we released the trial edition of MZ Platform, we developed IT systems using it with some manufacturing companies. Though the IT systems had sufficient functions for practical use, the companies did not use them. We conducted hearings to the companies and found that they had difficulties in assigning workers to operate, utilize, manage and maintain the IT systems. Then, we began to work hard on education of workers and establishment of a user support organization.

Diffusion is not only to deliver research results. It is important to think about the final use cases from the viewpoint of intended users and to plan a strategy for reaching the goal. We have learned this from this research, which has been instructive and useful for our future research.

We recognize MZ Platform to be almost completed as an IT system development tool. We will improve MZ Platform

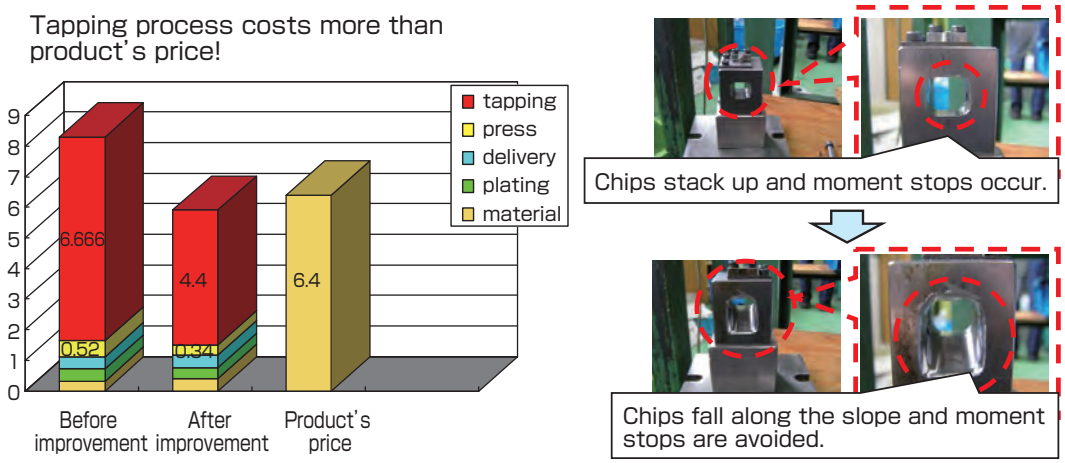

Fig. 9 Improvement of manufacturing process by utilizing the collected data (provided by Shotoku Zerotec)

continually by introducing available new technologies. Technology in the field of IT is progressing rapidly, and it is often the case that a technology not recognized five years before has become commonly used. MZ Platform has a mechanism to improve its functions by introducing a new technology as a new component. We are going to utilize MZ Platform not only for IT system development in manufacturing companies but also as a platform for our future research work by introducing new technologies . In addition, we will use MZ Platform to implement our research results as software applications and introduce them into companies.

Acknowledgement

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Discussions with Reviewers

1 Overall summary (Motoyuki Akamatsu, AIST)

This paper describes the development of a tool which enables users to make software applications without professional IT knowledge, in order to solve a problem of manufacturing SMEs having difficulties in developing and introducing IT systems due to heavy work load. Since it is difficult to make a software application by writing source codes, the authors developed a tool to build up an IT system by combining components without any source code writing. It is necessary to prepare a set of standard components in order to realize full component-based development. The authors used a strategy to make the standard components through development of IT systems for practical use with manufacturing companies. It is most important to diffuse the tool. The authors diffused it by organizing a support network consisting of manufacturing companies, software vendors, AIST and prefectural research institutes.

2 Standardization of components

Question (Motoyuki Akamatsu)

The authors claim that it is necessary to standardize components in order to realize full component-based development. What does “standardization” mean in this paper? What kind of components can be regarded as standard? In addition, please explain how to make standard components.

Comment (Naoki Ichikawa, AIST)

It would be better to explain the developing process of the

standardized components. Was there an initially established plan for the components under some assumption or was there a trial and error process to decide the components in accordance with practical specifications?

Answer (Hiroyuki Sawada)

"Standardization of components" means "preparation of a set of components with sufficient variety and generality which improves efficiency of development of an IT system satisfying various requirements of manufacturing companies." Each component belonging to the component set mentioned above is a standard component, which means a component based on the classes of standard functions. We added an explanation that we refer to "a component based on the classes of the standard functions" as "a standard component."

We made standard components by dividing and generalizing component functions for specific companies. We divided the component functions for specific companies and decided on standard functions applicable to the development of IT systems for various companies. On the other hand, we developed a new component with generic functions for similar functions used in IT systems of various companies. We added the above explanation in Section 2.2.2 "Preparation of standard components."

We firstly established our objective as preparing a set of components with sufficient variety and generality which improves efficiency of development of an IT system satisfying various requirements of manufacturing companies, and planned to make it possible to build up various IT systems by combining highly generic standard components. We made specific components to extract necessary functions for IT system development and to gain knowledge for preparing a set of standard components.

3 Demands on companies in IT system development

Comment (Naoki Ichikawa)

It might be necessary to mention an attitude which a company should have when introducing and developing an IT system. It would be better to clearly explain that a company would fail if it only expects something good as shown in the case studies. I recommend the authors to explain what a company should take into account; that is, to make the necessity, objective and effect of introducing an IT system clear before introducing an IT system.

Answer (Hiroyuki Sawada)

At the beginning of the paragraph that starts with "One is an issue of …" in Section 2.2.1 "Development of practical IT systems for manufacturing SMEs," we mentioned an issue of workflow analysis and described the importance of making the aim and objective of introducing an IT system clear.

4 Introduction of MZ Platform to companies

Comment (Naoki Ichikawa)

Though the authors write in a matter of fact manner, I think that they examined various alternatives during the development of MZ Platform. It would be better to explain at what stage of development they decided to introduce MZ Platform to companies, and important turning points at which they changed functions or specifications of MZ Platform by reflecting feedback from the companies.

Answer (Hiroyuki Sawada)

In the first part of Section 2.2.1 "Development of practical IT systems for manufacturing SMEs," we explained what we regarded as important in hearings to companies and the repeated process of evaluation and improvement during the IT system development. Furthermore, as the knowledge obtained from the process, we explained that classification of component functions is very important in making the best use of the advantage of the full component-based development method which improves IT systems easily.