The Application of Personal Digital Assistants as Mobile Computing Device on Construction Site

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ABSTRACT: Construction managers need to access the real construction site to manage the construction project. They have recently handled various types of digital information such as drawings, specification, checklists and daily reports. They usually use sheets of paper and/or field notes. As a result, a gap in time and space between the outdoor construction site and the office, which leads to the low efficiency, occurs.
This paper reports the application of PDA (Personal Digital Assistants) as mobile computing device for construction managers on construction sites. First, this paper describes the aim and the essential element of the mobile systems. This also shows the analysis of necessary functions as mobile computing device through the discussion with construction managers, and the concept of development of this computer-aided engineering system. Secondly, this paper describes the outline of below subsystems with PDA: Progress Monitoring System, Inspection System and Position Check System. Subsystems have two programs: the data input program in PDA and the output program in PC. Finally, this paper indicates the development of more refined process of construction management with the mobile computing device on construction site.

- Progress Monitoring System has been built for construction managers to monitor the progress of works. This is especially useful for apartment building projects because of the large number of rooms. Construction managers can share the current progress of all rooms soon.
- Inspection System has been built for construction managers to inspect the result of construction. PDA displays the code and/or checklists each building element and work. They plot the position of unacceptable on a drawing and select related items from the lists in PDA. The output program of the system in PC can print the instruction document for subcontractors to correct improper workmanship.
- Position Check System has been built for construction managers to check the position of steel members in the structural steel erection. The output program of the system in PC can show the actual form of steel frame considering the fabric distortion graphically and the scatter of accuracy of steel erection with graph.

KEYWORDS: mobile computer, personal digital assistants, input and output device, construction site, inspection, monitoring.

1. INTRODUCTION

Various kinds of mobile device has been adopted to field jobs on construction sites. In the case of Japan, the bar-code system had been used as the data input device in the late 1980s. The electric pocketbook was commercialized in 1987 and had been used as mobile device in the early 1990s. The laptop PC has been used too. The systems developed by general contractors in this period are the prototype of the current mobile systems in construction industry. During the mid of 1990s, some computer manufactures have produced handheld PC and palm-size PC. Their function has advanced year after year. The current PDA, which is a current palm-size PC, can handle the various types of data including not only texts but also drawings and pictures. The processing speed of PDA has also developed.
On the other hand, office automation from the early 1990s improves the productivity of office works. However, construction managers still have a lot of typical and routine jobs in construction site, such as the collection of construction data and the inspection. Authors think that current mobile computers can improve the system of field work of construction managers and enhance the total productivity of construction management.

2. MOBILE COMPUTING SYSTEM

2.1 What does the mobile computing change?

Construction managers usually need to access the outdoor construction site. PC is an essential tool in construction management today. However, the current PC is not suitable for the outdoor use. They usually use sheets of paper and/or field notes for outdoor jobs. As a result, a gap in time and space between the outdoor construction site and the indoor office occurs. This gap can cause the duplex, lack and confusion of data.
Mobile Computing System can function to eliminate this gap. Digital data input with the mobile system will be used quickly and effectively. Computer-aided engineering tools linked with the mobile system support construction management. As a result, the total system will realize the labor saving and the rationalization.
As each job in construction is strictly scheduled, construction manager must make decision within time. Free float by the labor saving will generate the full thinking time for construction managers.

2.2 What is necessary for the mobile computing of construction management?

Construction is usually outdoor. Authors arranged the necessary functions for the mobile computing system and its devices through the interview and discussion with construction managers.

- Mobility of Hardware: Construction managers want the pocket size of hardware.
- Durability of Hardware: The strength for the physical shock, the rain, the wet and the dust is necessary for hardware.
- Compatibility of Hardware and OS: It is suitable that the system can work on any hardware and any OS (Operating System).
- Compatibility of Data between Mobile and PC: Construction managers want to use the data in PC on the mobile device. The converse is also necessary.
- Expressivity of Display: The sufficient expressivity of drawings and pictures on the mobile both indoor and outdoor is necessary.
- Stability of System: Total stability of system including OS, memory card and other devices is necessary.
- Operability of User Interface: Construction managers want to input data with gloves. Easy user interface by pen-touch is suitable.
- Speed of Operation: Start-up, Shut-down and each calculation of the mobile system needs quick response.
- Continuous Computing Environment: The computing environment has recently changed quickly. Construction managers want continuing to use the system for a long time. The computing environment that assures the long operation of systems is necessary.
- End User Computing: Construction is usually based on a project, which has unique features and/or limitations. Construction managers need the flexibility of computing system for a project. EUC (End User Computing) has also been realized in the mobile computing. Users can build subsystems for various kinds of field jobs in construction management, considering the unique features and limitations of project.

After discussing the necessary functions as the mobile computing system and devices of construction management, authors have adopted PDA as mobile computer to deal with current assignments.

2.3 Structure of Mobile Computing System

Mobile Computing System has some subsystems that basically have two programs: the data input program in PDA and the output and analysis program in PC. Figure 1 shows the operation of two programs and data transfer between them.
Operation on PDA is executed by pushing the button or selecting the item from the list with pen-touch. Users can also input the content out of the list freely. Like this, all of data is easily stored in a memory card installed to PDA.
Users transfer the data from a memory card to PC in the office. Data transfer with mobile phone will be possible soon. The current system adopts spreadsheet software as database to store the data. Users can share all of the data. At the same time, users can use the system individually.
Users can output various arrangement and analysis of data by the system and other computer-aided engineering systems in PC.

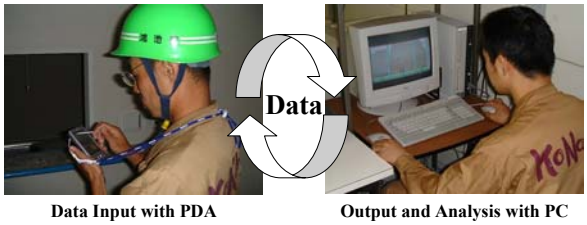

Figure 1. Data Transfer between PDA and PC

3. MOBILE COMPUTING SYSTEM

Figure 2 shows the cover screen of Mobile Computing System. Users select project name, and user name or inspection type such as general contractor's inspection and supervisor's inspection. Figure 3 shows the screen of selection of Subsystems. Current Mobile Computing System has four subsystems: Progress Monitoring System, Field Note System, Inspection System and Position Check System.
The integrated system shares the necessary data effectively.

3.1 Progress Monitoring System

Progress Monitoring System is to monitor the progress of construction work. Users can set the division of work freely. The application of this system for finish work in apartment building project is more useful because finish works of multi dwellings progress at several places simultaneously.
Figure 4 shows the screen of data input of progress on PDA. For each division of progress, users input the progress information such as "no start," "start," and "finish."
Figure 6 is an example of the graphical expression of construction progress on PC by Progress Monitoring System. This model has three buildings and nearly 360 dwelling units.

3.2 Field Note System

Field Note System is to note various unacceptable or notifications on construction site and to make the instructions for subcontractors.
Figure 5 shows the data input screen of position of an unacceptable on PDA. Users determine the position of unacceptable and, after that, select and/or input the contents. Users can select the items from the lists, which they can make them out previously, and/or can input the contents freely on PDA. The advanced function: the character recognition enhances the actual use of PDA. The contents in this current system are roughly classified into three categories: safety management, quality management, and environmental management.
Figure 7 is an example of output of instruction for subcontractors. It reproduces the position and contents of unacceptable or notifications. Users can coordinate the output by the sort function. They usually print the output by the kinds of subcontractors.

Figure 2. Cover Screen

Figure 3. Selection of Subsystems

Figure 4. Progress Input Screen

Figure 5. Pointing on Drawing

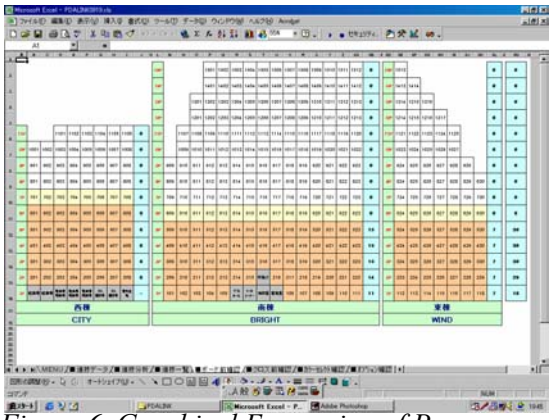

Figure 6. Graphical Expression of Progress

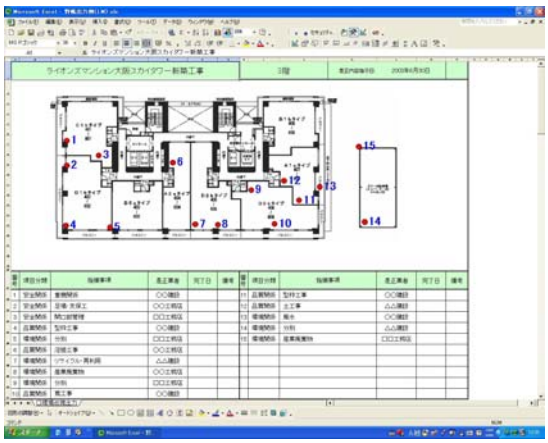

Figure 7 Output of Field Note

3.3 Inspection System

Inspection System is to inspect the result of construction, especially for finish works, and to make the instructions for subcontractors. Like Field Note System, users can select the items from the lists, which they can make them out previously, and/or can input the contents freely on PDA. This is more useful for multiple dwellings because they have many dwelling units and rooms.

Figure 8 shows an example of display of one dwelling unit on PDA. This screen shows the type and room planning of the dwelling unit.
When users input the data, the screen of enlarged room planning appears (See Figure 9). After pointing the position of unacceptable, they select the items from the lists and/or input the contents. Figure 10 shows an example of lists. The flow of data input of one pointing in finish work is as follows: 1) Room Name such as "living room" and "kitchen," 2) Building Element such as "wall" and "floor," 3) Finish Material such as "wall paper" and "carpet tile," 4) Unacceptable Indication such as "dirt" and "crack", and 5) Related Subcontractors such as "finishing carpentry" and "glazing work." Users can make all contents of lists previously. They can prepare multiple patterns for the lists: Room Name and Related Sub-contractors because different dwelling units may have different kinds of rooms and multiple subcontractors may be engaged in the same work in one project. The lists: Unacceptable Indication and Related Subcontractors depend on the result of selection of Finish Material. This relation enhance the efficiency of selection of item from the list.
Figure 11 shows an example of all input data of one indication on PDA in Inspection System.

Figure 12 is an example of output of instruction for subcontractors in the inspection for finish work. It reproduces the position and contents of unacceptable and/or notifications. Users can coordinate the output by the sort function. Like Field Note System, they usually make the output by the kinds of subcontractors and the type of Inspection such as general contractor's inspection and supervisor's inspection.

Digital data can generate the added value. For instance, figure 13 shows the room organization of unacceptable indication in the inspection of one dwelling unit and the building element organization of the living room. The analysis will be reflected to the next planning and management.

Figure 8.
Dwelling Unit Screen

Figure 9.
Positioning on Drawing

Figure 10.
List Screen

Figure 11.
Input Contents

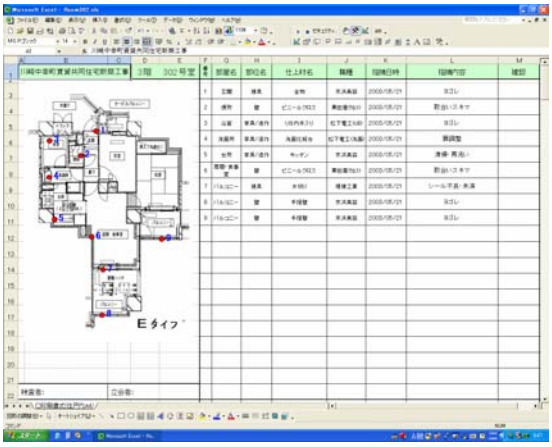

Figure 12. Instruction for Subcontractors

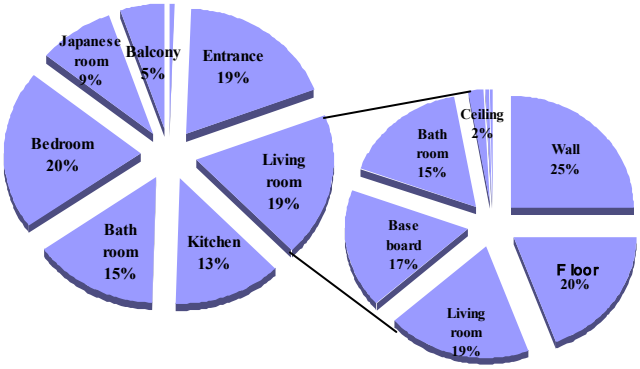

Figure 13. Analysis of Inspection Data

3.4 Position Check System

Position Check System is to check and record the position of building members, especially for the steel erection, and to show the actual condition of construction graphically.

Figure 14 shows the screen of selection of steel members on PDA. This system prepares three occasions of data input of position for one steel member: "before welding," "after welding" and "after concrete-casting."
Figure 15 shows the screen of numerical data input of position on PDA. This system adopts the scroll bar for users on construction site to input data easily and quickly.
Position Check System can show the current condition of steel frame on PC graphically. Figure 16 is an example of actual position of steel members: columns and beams (The defects are enlarged 150 times). It also shows the numerical values: the three-dimensional position of the top of steel columns, and the expansion and contraction of steel beams.

Figure 17 shows the distribution of their positions with the histogram by three-dimension.
These outputs also consist of the report of quality management for the steel erection.

It is said that the welding of steel members and the error of size of steel members are factors of the above disorder. Authors consider the establishment of feedback system of the result for the planning and management.

4. EFFECT OF MOBILE COMPUTING SYSTEM

One of aims of Mobile Computing System is the improvement of productivity of construction management. Figure 18 shows the comparison of productivities of the inspection for finish work per 30 dwelling units (The result of conventional system is a simulation based on construction manager's experience). The job with PDA needs more time for the preparation but reduces the time of the data reduction and instruction print.

Another is the mobility of data and information in PC. General contractors in Japan are positive for sharing knowledge: the code, the checklist for various jobs and the related information. They usually arrange and store them in their own intranet from the viewpoint of knowledge management. Construction managers can bring them freely with Mobile Computing System.

Figure 14. Selection of Column

Figure 15. Numerical Data Input

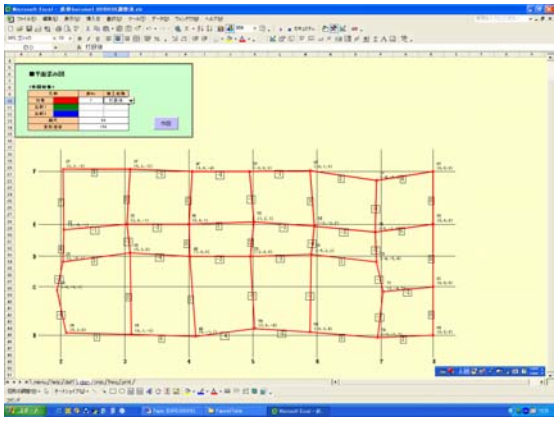

Figure 16. Actual Condition of Steel Frame

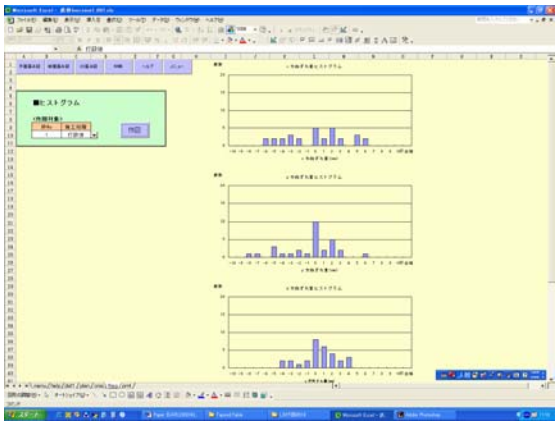

Figure 17. Histogram of Position Data

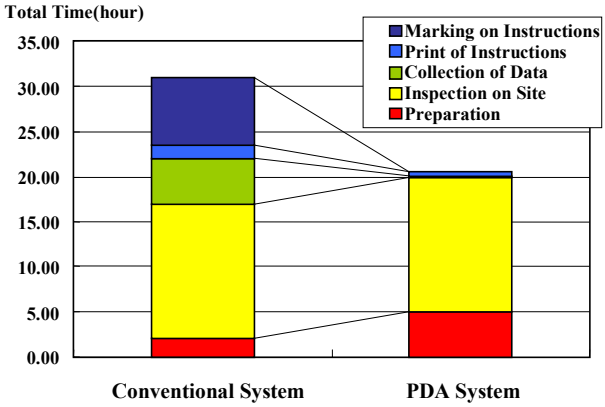

Figure 18. Comparison of Productivity

5. CONCLUSIONS

This paper describes the aim and outline of Mobile Computing System. Authors examined necessary functions for the mobile system and adopted PDA as mobile computer.

The following conclusions can be drawn by establishing Mobile Computing System and analyzing various data:

- Mobility of Information: The mobile system can offer the information of PC in the indoor office on construction site.
- Increase of Productivity: The mobile system can realize the increase of productivity of construction manager. Although, preparation needs more time, the man-power of data reduction and output are decreased.
- Link of Existing CAE tools: Quick data input with the mobile system can realize the effective use of data with the link of existing computer-aided engineering within time. This will leads the rational decision-making by construction manager.
- End User Computing: End User Computing is important especially in the application of computer-aided engineering for construction management because construction projects have many unique features and limitations.

Next Generation of Mobile Computing System can be modeled as follows:

- Digital Camera: Digital camera has already installed the mobile computing devices. The function of attaching the information to each picture on the mobile easily is needed.
- Speech Recognition: The function of speech recognition has already established. The elimination of noise on construction site and the conversion from speech about construction to character are needed.
- Real Time Data Exchange: Various construction works on construction site proceed simultaneously. Real time recognition of construction site leads better management. The application of mobile phone including cellular phone will be possible and suitable.
- Compatibility of Hardware and OS: In actual, various types of mobile computer and OS exist. The compatibility will be necessary to spread the application of computer-aided engineering.

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