

DEVELOPMENT OF A DRAWING BASED INFORMATION SHARING TOOL USING HANDHELD COMPUTER (APPLICATION TO A FINISHED WORK INSPECTION AND A BUILDING DIAGNOSIS)

Tomoya Kaneko
Technical Research Institute
Obayashi Corporation
kaneko.tomoya@obayashi.co.jp

Abstract: A seamless means of distributing information between a job site and a site office is often necessary in construction management. Most information written on drawings shows locations. We developed an information sharing tool with a drawing based interface that runs on both a desktop computer and handheld computer, as well as two applications that use this tool. The finished work inspection tool automatically prints instruction forms for the subcontractor, thus reducing the duration of the finished work inspection. The building diagnosis tool supports investigation for renewal of existing facilities, and provides an environment for editing the diagnosis reports for the facility owner and reduces the total manpower required for diagnosis.

Keywords: Drawing, Information Sharing, Handheld Computer, Finished Work Inspection, Building Diagnosis

1. INTRODUCTION

A seamless information distribution means between a job site and a site office is often necessary in construction projects, but most information written on drawings shows locations. We therefore developed an information sharing tool with a drawing based interface that runs on both desktop and handheld computers, and developed two application systems that use the tool. The present paper shows the targets and functions of the drawing based information sharing tool, an outline of the finished work inspection system, and a building diagnosis support system including the application results.

2. DRAWING BASED INFORMATION SHARING TOOL

2.1 Target

The idea that portable devices help information distribution in a construction project is not new. Mori and Amou developed a finished work management system using a portable computer (1992) [1]. The device had functions for showing plan drawings that could be written on using a touch screen and stylus without needing a keyboard.

We previously developed and applied an inspection support system [2] using a similar but advanced device (Fig. 1). We showed that the drawing based interface reduces the amount of text required to describe a situation and assists the accurate distribution of information, but the following problems remained to be solved:

- The device is large and heavy to carry.
- Data synchronization among multiple devices is necessary for use on large projects.

To solve these problems we developed a drawing based information sharing tool using a handheld device with graphical user interface. The development objectives were

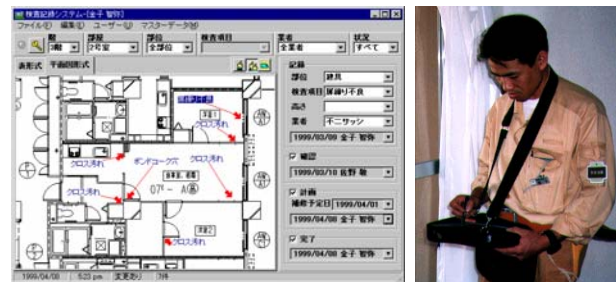


Fig. 1. An inspection support system

as follows.

- To provide users with similar operability between handheld and desktop computers.
- To provide a light and smooth drawing based interface even on a handheld computer which has a lower display resolution and slower CPU than a desktop computer.
- To enable the user to synchronize and share information between one or more devices.
- To enable the user to easily add extension software modules as needed.

2.1 Functions

The functional structure of the tool is shown in Fig. 2. The tool provides basic functions such as a drawing interface, icon operation and synchronization within the desktop computer and handheld computer. These functions are common to application systems which will be developed based on the tool.

1) Drawing based interface

Figure 3 shows the interface of the tool running on desktop and handheld computers. On the drawing interface, each data consists of an area or an arrow that shows a location, an icon that indicates the kind of data, a caption,

and a link if necessary. The user can move them by mouse operation.

Each kind of data has its own property dialog box which allows the user to view or edit the contents of the data. To create new data, the user selects an icon and locates it by clicking.

As background image files, bitmap, JPEG and HBS (hierarchical bitmap set) can be used. HBS is a special format for the tool which enables large images to be viewed on a handheld computer. Figure 4 shows the concept of HBS. In the format, a few steps of scaled-down images are prepared and then divided into image pieces of the same size. When the tool needs to show a part of the original image as a background, the optimum scaled-down series is selected and only the image pieces that include the required range are loaded into main memory (Fig. 5). This is effective for a handheld computer which has a low-resolution display and limited main memory.

The inclusion of scaled-down images increases the HBS file size by 10–20% over the original file size. To decrease the file size, HBS has two compression options, jpeg and range encoding. In both options, compressing each image piece reduces the whole file size, whereas the range encoding option reduces the file size by up to 90%. The tool includes an HBS converter.

Although WMF and EMF can also be used on the desktop version, the handheld computer cannot use them.

Both the vertical and horizontal axes are reliable means to find an object's coordinates in a drawing. Since the names of axes are generally placed on the edges of a drawing, magnifying a part of a drawing may remove them from sight especially on a low-resolution display. To solve this problem the tool provides an axis guidance option. Figure 6 shows how to set the axis guidance in the drawing registration window (on the left) and the drawing interface with the axis guidance (on the right). In the window the user can specify both the vertical and horizontal area of axes names with mainly the visible area in a background image. As a result, the drawing interface has horizontal and vertical guide areas for axes names. The guide areas are scaled up or down synchronized with the scale of the main area. The horizontal shifts in the main area and horizontal guide area are synchronized, while the vertical shifts are synchronized similarly, so the names of axes always remain visible in the drawing interface.

2) Icon arrangement

Since crowded icons reduce the legibility and operability of the drawing interface, the user wants to use arrows and links and arrange icons along the edge of a background image, so the tool has an icon arrangement function (Fig. 7).

The algorithm of the arrangement is as follows.

- Generation of rooms for icons: Rooms for icons are generated on the edge of the background image. The number of rooms must be the same or greater than the number of icons. The intervals between rooms do not have to be the same.

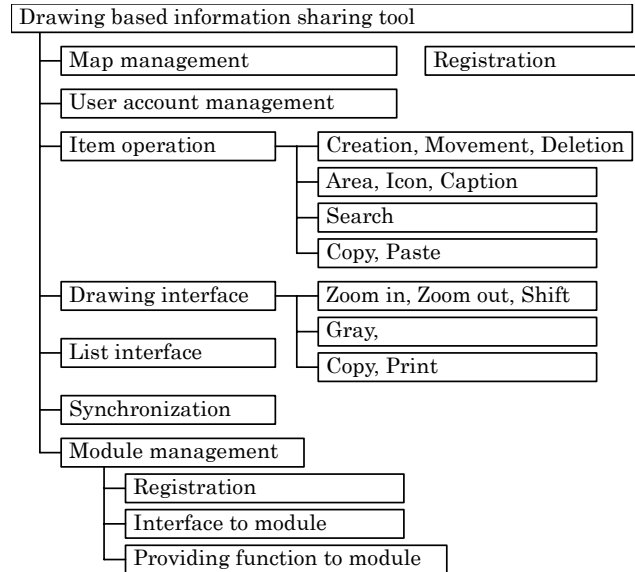


Fig. 2 Functional structure of the tool



Fig. 3 Drawing based interface

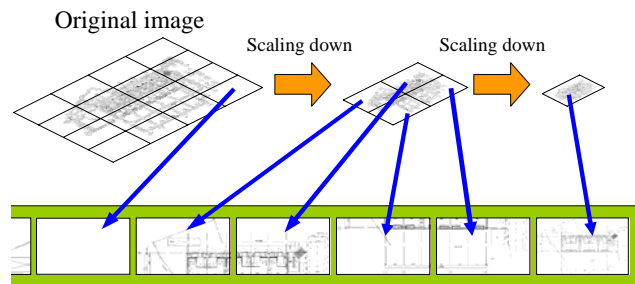


Fig. 4 Concept of HBS



Fig. 5. Advantages of HBS

- Optimization of combination of arrow heads and icon room: The combination of arrow heads and icon rooms is optimized by minimizing the sum of each distance between arrow head and icon room.

Since the function arranges icons only and arrow heads are never moved, the user can arrange options as a trial at any time.

3) Extensibility by software modules

The functions of the tool are extended by connecting software modules; this is done by Windows DLL (dynamic link library) exporting the required functions. Figure 8 shows the relation between the tool and extensible software modules. There are the following three types of module:

- Data access module: This stores and retrieves data. A standard version of this module uses Microsoft Access's MDB file as a database.
- Background drawing module: This opens image files and provides a background image as the drawing interface.
- Class library module: This provides icons and property dialog boxes.

The tool calls a function provided by a module complying with the user's operation. A first argument (parameter) of the function is always a reference to a table which contains over 150 functions provided by the tool. A module's function is implemented by calling these functions.

4) Synchronization

Since desktop computers on a network can share a database, a synchronization strategy among them is not necessary without transaction control. However, information-sharing on off-line communication among the desktop computer and handheld computers needs a precise strategy for synchronization.

The unit of synchronization is a record which corresponds to an icon. A record has fields for unique ID, latest modified time (modify_time) and state of synchronization (sync_state). Sync_state takes one of the values of *New*, *Shared*, *Hidden*, and *Modified*.

On the desktop computer, a newly appended record has the Sync_state value of *New* and the record can be completely removed by deletion. Once the record is exported to the handheld computer, its Sync_state changes to *Shared*. Thereafter, its Sync_state changes to *Hidden* by deletion and it is hidden from the drawing based interface.

On exporting to a handheld computer, records whose modify_time field is greater than the latest exported to the handheld computer are copied.

On the handheld computer, the newly appended record has the Sync_state value of *New* and the record can be completely removed by deletion. A record exported from a desktop computer has the Sync_state value of *Shared*. The value changes into *Hidden* by deletion and into *Modified* by modification.

On importing from the handheld computer, records whose Sync_state is *New*, *Modified* and *Hidden* are

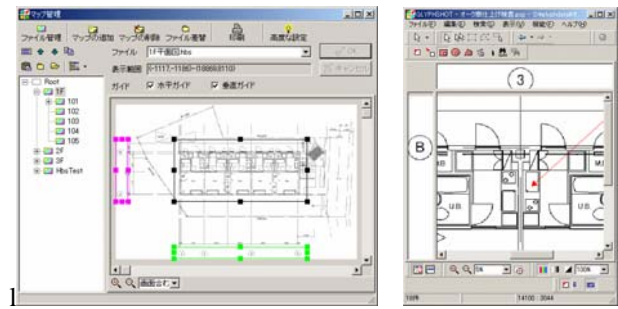


Fig. 6. Setting and use of axis guidance

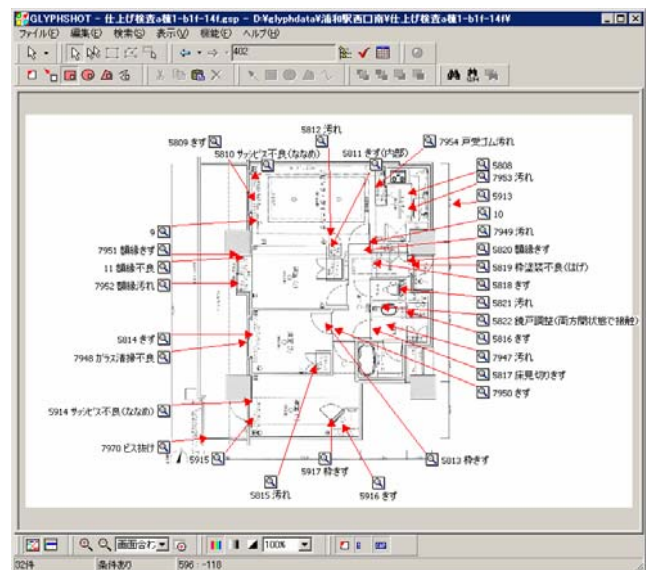
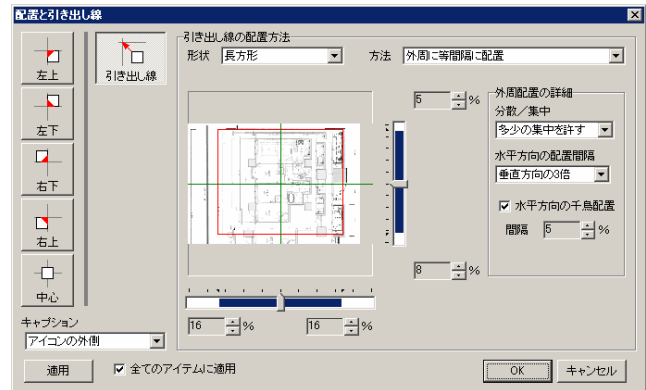


Fig. 7. Automated icon arrangement

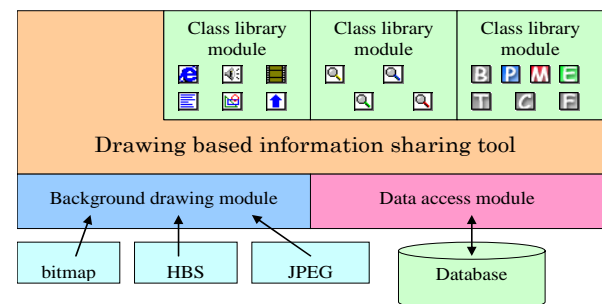


Fig. 8. Relation between the tool and module

imported. Upon importing a record whose Sync_state value is *New*, if a collision of ID occurs, the tool allocates a new unique ID. Upon importing a record whose Sync_state value is *Modified* or *Hidden*, records whose modify_time field is greater than the field of the corresponding record in the desktop computer are copied.

3. FINISHED WORK INSPECTION SYSTEM

3.1 Purpose of development

The finished work inspection is done by the busy construction manager just before the completion of construction. Conventionally, the manager takes the plan drawings with him to site and writes down the places that need to be fixed or cleaned. He then creates an instruction sheet called a “punch list” for subcontractors who will perform the fixing or cleaning.

Especially in apartment construction, the finished work inspection needs to be supported by information technology for the following reasons.

- The finished work inspection is repeated several times by different people, including the construction manager, quality assurance department, designer, client and tenant.
- The construction of high-rise apartments in large-scale redevelopment projects which include many houses is increasing.
- The increase in apartment construction allows tenants to choose the interior design, which complicates the inspection.

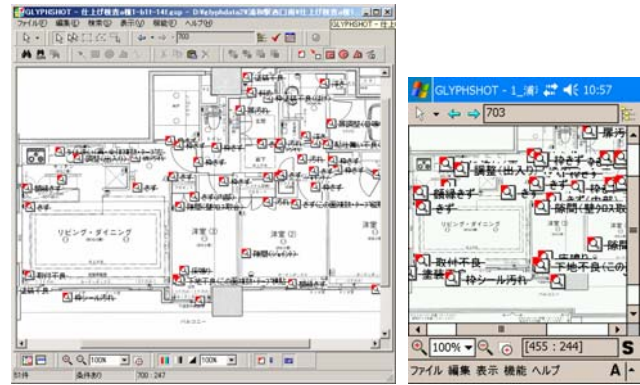
We have developed a finished work inspection system based on the tool and applied it to actual construction projects.

3.2 Outline of functions

The system has functions for recording inspection results, managing master data and printing instruction reports in addition to the functions inherited from the tool.

Figure 9 shows a drawing based interface of the system. The icon is an image of a magnifying glass. The caption shows a specific defect and the strike-through font is used after completion of fixing or cleaning.

Figure 10 shows the property dialog box of the finished work inspection, which pops up from the icon. In this dialog box the user can set items such as the kind of inspection, room type, building element, details of defect, and type of subcontractor in charge of fixing or cleaning the defect. The values of these items are selected from a pull-down list. A house number (name) is automatically set from the name of the drawing which is visible when the icon is put on it. The company name of the subcontractor is also set automatically according to the combination of house number and kind of subcontractor. After the defect has been fixed or cleaned, the date and time it was fixed is set by clicking a button. The dialog box has two other pages: a page for two additional types of subcontractor and a page for memos.



Desktop version Handheld version
Fig. 9 Interface of finished work inspection system



Desktop version Handheld version
Fig. 10 Property dialog box of finished work inspection

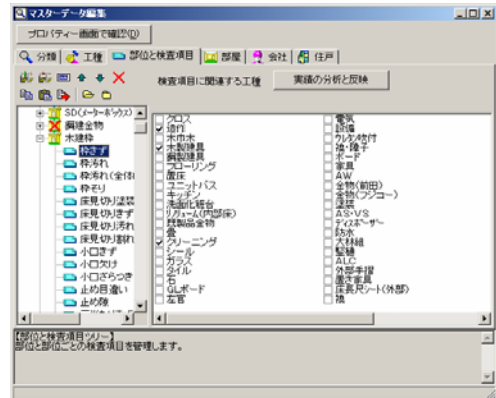


Fig. 11 Master data management dialog box

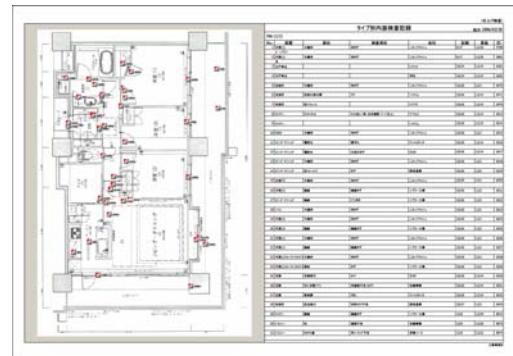


Fig. 12 Sample of finished work inspection report

Figure 11 shows a dialog box for master data, by which the user can add and delete values of the items that appear in the property dialog box.

There are two ways of creating an instruction report: directly outputting to a printer and creating a data file of a spreadsheet. The latter is convenient when the owner specifies a report form because its format can be set by a template file of the spreadsheet.

3.3 Outline of application

1) High-rise apartment building construction

This system was used for the construction of a high-rise building project in Nagasaki city which contained 194 apartments. In the project the owner demanded a fair copy of the instruction report for each inspection. In another project, rewriting by spreadsheet took 6 hours for three construction managers.

By using the system, the instructions to subcontractors and reports to the owner were printed in just one hour for each. The system thus saved the cost of hiring two temporary workers for three months which would have been necessary for the finished work inspection.

2) Large-scale redevelopment

The system was used in a large-scale redevelopment project in Saitama city, which included 256 apartments. In the project, finished work inspections by the construction manager, developer and owner were done two times for each person, and the finished work inspection by the tenants was done three times. The software was installed on 19 desktop computers linked by a local area network in a site office.

The total amount of inspection data was 42,350 items. For the inspections by the tenants, desktop computers were used to distribute the input load.

3.4 Benefits of the system

We have applied the system to 41 projects and confirmed the following benefits.

- The time taken for input to a handheld computer can be shortened, by experience, to as short as writing by hand on paper.
- The inspection reports are printed automatically, which is particularly effective when the owner demands fair copies of the report.
- Even without using a handheld computer, the system is beneficial for report-printing by inputting from a desktop computer.
- The system helps users to become skillful at finished work inspections.

We supply the system to all site offices as standard software for construction management.

4. BUILDING DIAGNOSIS SUPPORT SYSTEM

4.1 Purpose of Development

Renewal construction projects have recently been increasing in Japan. Obayashi Corporation established its Renewal Project Department in 1993 and started a building

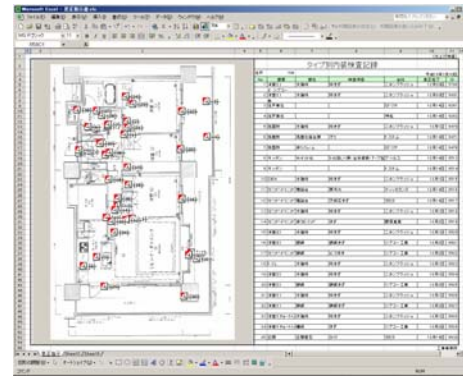
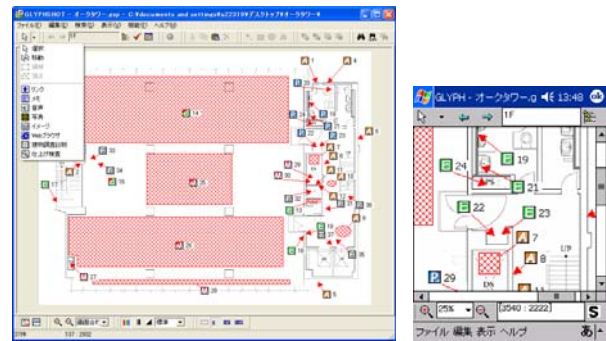


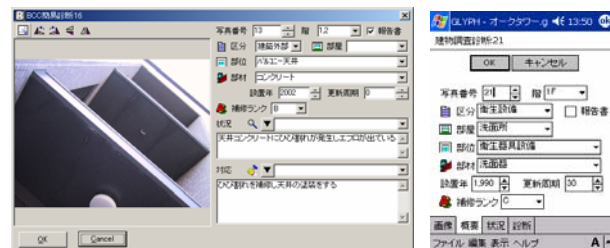
Fig. 13 Sample of finished work inspection report



Photo 1 finished work inspection



Desktop version Handheld version
Fig. 14 Interface of building diagnosis system



Desktop version Handheld version
Fig. 15 Property dialog box of building diagnosis

diagnosis service for existing facilities. Building diagnosis requires in-depth knowledge of buildings and equipment and a quick response to the building owner for renewal of the building.

We have developed a building diagnosis system based on the tool and applied it to actual construction projects.

4.2 Outline of Functions

The system has functions for recording diagnosis results, managing master data and printing instruction reports, in addition to functions inherited from the tool.

Figure 14 shows the drawing based interface of the system. The icon shows the first letter of the category name, for example “P” meaning “Piping”.

The system provides a database for building diagnosis which includes keywords extracted from previous building diagnosis reports. Fig. 15 shows the property dialog box of building diagnosis, which pops up from the icon. In this dialog box the user can set items of diagnosis category, building element/equipment name, building material/equipment type, and importance of renewal. According to the values of these items, the system looks up suitable keywords for situations and countermeasures in the database. The user can then edit the explanation of damage and way of dealing with it using the keywords. Digital photos can also be registered in the dialog box.

4.3 Outline of application

Table 1 shows the results of using the system. The system is standard software for building diagnosis in the Renewal Project Department.

4.4 Benefits of the system

From the applications we have confirmed the following benefits:

- The database for building diagnosis allows provides standardization of terms and consistent quality of diagnosis.
- The system reduces the time taken for editing the diagnosis report to 70%.
- The system provides an environment for keeping together materials for the report, including digital photos.

5. CONCLUSION

We have developed an information sharing tool with a drawing based interface that runs on both a desktop computer and handheld computer, and have developed two applications using this tool. The finished work inspection system automatically prints instruction forms for the subcontractor, and the time required for finished work inspections was reduced. The building diagnosis tool supports investigation for renewal of existing facilities, and provides an environment for editing the diagnosis reports for the facility owner and reduces the total manpower required for diagnosis.

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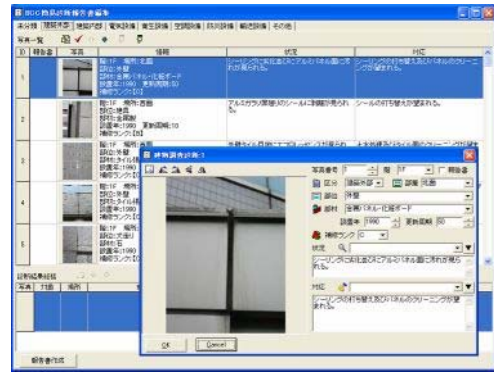


Fig. 16 Report editing dialog box

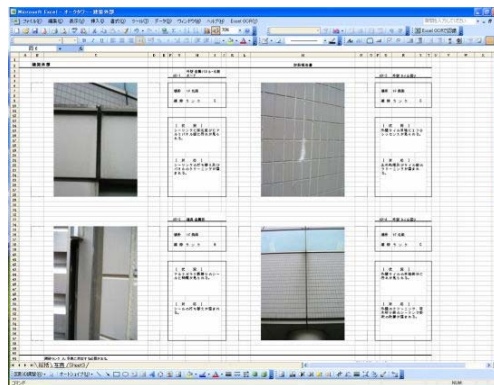


Fig. 17 Sample of building diagnosis report

Table 1 results of building diagnosis system

Building use	Buildings	Total floor area (sq.m.)
Office	39	460,272
Plant	45	338,259
Storehouse	23	22,033
Gymnasium	9	33,452
Shopping center	1	1,391
Parking	1	12,316
Other	5	215
Total	122	855,622

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