Constructing a User Interface for Cellular Phones
Using Equipment and its Relations

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ABSTRACT

In a domain of SCADA (Supervisory Control And Data Acquisition) systems, it is necessary to obtain information about plants such as water plants in remote places using a cellular phone in order to ascertain plant status in case of emergency. To utilize the small screen of a cellular phone and to eliminate the engineering cost of creating definition data to show plant status, a method of constructing user interface using equipment in the plant and its relations is proposed. In this method, some equipment is selected from all supervised equipment using the relations between the equipment, and then the content to be displayed is generated dynamically using the selected equipment. The equipment in plants is organized as a graph structure, which involves the equipment and the relations between the equipment. The relations adopted in this method are both the physical connections between the equipment and the conceptual relationships. The result of the selection depends on the relations and their parameter values called the context dependent weight, which changes dynamically by viewpoints.

Keywords: SCADA system, mobile application, cellular phone, plant modeling, small screen visualization and information retrieval

1   Introduction

In a domain of SCADA (Supervisory Control And Data Acquisition) systems, it is necessary to obtain information about plants in remote places using a mobile device. The information involves monitoring status and recent alarms, and is always shown on computer screens in the control rooms of plants. However, there is no plant operator in a control room during holidays, nights, or on-the-spot maintenance in the field. When an accident or failure happens at a plant on a holiday and no one is in the control room, remote plant operators must obtain enough information to decide whether they should rush to the plant or not.
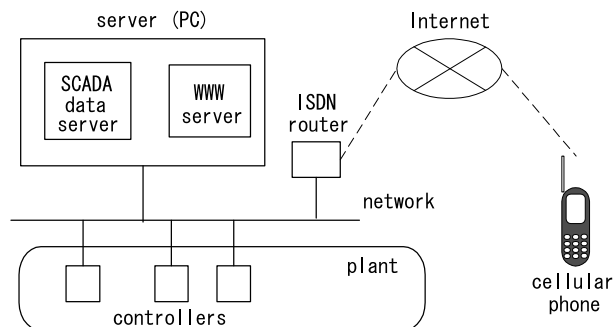

Figure 1: System architecture

Operators want smaller, easier-to-carry devices than PCs (personal computers) for obtaining this information from remote places. Using a PC as a remote device, many PC systems using WWW (world wide web) technology, such as Java applets and WWW browsers, are already commercially available. The FIX Web Server[1], for example, based on Java applets that shows plant states graphically. A notebook PC is however too large for operators to carry along all day on holidays.

Cellular phones enable people to get information over the Internet in many countries. WWW-enabled phones ("browser phones"), and Java-enabled phones ("Java phones") are commercially available and have become very popular in Japan. Both can communicate with a WWW server over HTTP (hypertext transfer protocol), so it is easy to get information simply by integrating a system such as shown in Figure 1. Though PDAs (personal digital assistants) are also available, the operators in Japan dislike to carry PDAs because of its size.

Nevertheless, a cellular phone has the following two limitations: (i) A screen size is small (3 cm x 3 cm) and resolution is 120 x 120 pixels or so. The screen can contain 99 characters (9 lines) in the smallest font. (ii) Only about 20 buttons are provided for input. There are no pointing devices except for four scroll buttons

Figure 2: A screen on a cellular phone

Figure 3: Screens to obtain equipment status

(up, down, left and right). To input texts, users have to make full use of the number buttons.

These limitations lead to two problems in applying cellular phones for monitoring large or medium plants. As the size of the page is smaller than the screen size of PCs, the number of page definitions increases. The first problem is that it becomes difficult to jump to another desired page, because the number of buttons is small and it is difficult to display an exhaustive, convenient menu without a deep hierarchy. In case of emergency, an easier way to move to another page is required than in ordinary cases.

The second problem is the system integrating cost. If the system requires content description for each page, creating page data and their maintenance requires extra cost from the viewpoint of the amount of data and of dividing and designing the pages. If the page becomes smaller, the number of page content definition increases at a much faster rate, because each small piece must overlap another to make sense itself.

The former problem is well recognized and many techniques have been introduced in various applications. Fisheye visualization[2] is one of the major approaches. For a pop-up menu and pulldown menu, for example, to show an exhaustive and convenient menu on a small screen, the fisheye menu[3] shrinks the menu items that are far from the focused one and shows all menu items at the same time. This approach, however, is not appropriate for such a small screen because there is no space to display the non-focused, shrunk menu items.
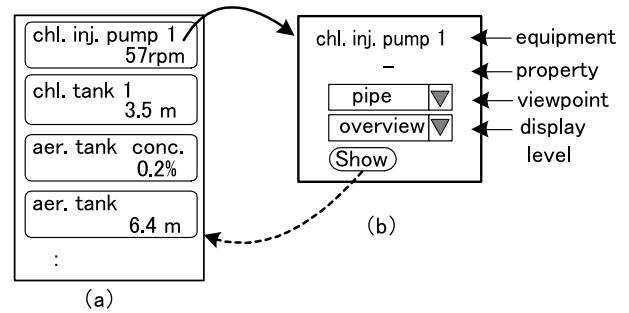
In this paper, we propose a method of constructing a user interface using equipment in the plant and its relations. Our approach is based on an equipment model in order to visualize important information in case of emergency. In this method, related equipment is retrieved by using the relations between the equipment, and then the content to be displayed is generated dynamically using the selected equipment.

The characteristics of this method are as follows: (A) a graph structure, which is composed of supervised equipment and various kinds of relations, and (B) labeled arcs of the graph, which are qualified according to their relation strength by weight values.

In this paper, at first an example of a mobile plant monitoring system is explained to clarify an application domain. Next, modeling of supervised equipment, the context dependent weight that is used for controlling selection, and an algorithm to select candidate equipment based on the model are described. Finally, related works are discussed.

2 Mobile Plant Monitoring System

In this section, an example of a mobile plant monitoring system is explained to clarify an application domain of the proposed method.

Figure 2 shows an example of a screen image of the mobile plant monitoring system.

When an accident has occurred, operators first check the status of the alarm-occurring equipment and then check the equipment related to it. The system works as follows: When a failure occurs at a plant and an alarm is raised, a notification is sent by telephone or e-mail automatically by the system. After the operator confirms the notification and sends a request to the system, the system looks for the equipment causing the latest alarm, determines a viewpoint corresponding to the alarm, and selects the equipment. The system then generates and displays the appropri-

ate initial screen. The screen may include the name of the selected equipment and the value of the property that are related to the alarm. If the property is not specified, the selected equipment uses and displays a default property specified beforehand according to the type of the equipment.

Figure 3 shows the interaction of the system. When a piece of equipment in screen (a) is selected, screen (b) is shown so that operators can specify next conditions. Then, when the "display" button in (b) is pushed after a viewpoint and a display level have been set, the selection is executed under those conditions, and the following screen similar to (a) is shown.

In order to discern plant status sufficiently, the system has the following four functions to display other contents. (i) The other equipment in the display is specified as the start equipment, and the selection is performed again at the same viewpoint. (ii) The selection is performed again from a different viewpoint with the same equipment. (iii) Detail selection of the equipment displayed in the screen is performed to give very detailed information about it. (iv) Outline selection of the equipment displayed in the screen is performed to display broader information.

3 Modeling of Equipment

Graph Structure of Equipment

According to the proposed method, each piece of equipment is modeled as an object in an object-oriented methodology, and current states of the equipment, which may be measured values, are assigned to properties of the equipment object.

Equipment objects and the relations between equipment objects form a graph structure. The equipment corresponds to a node and the relation corresponds to an arc. Both the physical and conceptual relationships are dealt with as relations. Some relations may be physical connections, such as pipes or power lines, and some may be conceptual, such as the role of the equipment. Figure 4 shows an example of the graph structure of equipment in a water plant domain.

Both the physical connections and conceptual relations are involved in Figure 4. There are relations between the equipment including "Pipe" for connected pipes, "Power" for connected power lines, "A-part-of" for pieces of equipment that are a part of other equipment, "Control" for a relation between a controller and controlled equipment, and "Same" for pieces of equipment that have the same role. "Pipe", "Power", "A-part-of", and "Control" are physical relations, and "Same" is a conceptual relation. A relation connects not only between equipment, but also connects equipment with the property of the equipment, or connects
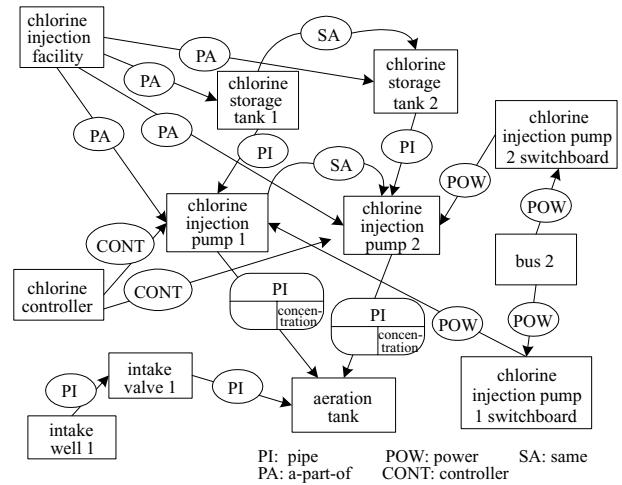

Figure 4: Graph structure of a water plant (extracted)

Table 1: Weight of a relation dependent on viewpoint

	Viewpoint			
Relation	general	pipe	power line	pipe only
Pipe	3	2	6	2
Power	3	6	2	20
A-part-of(normal)	4	5	5	20
A-part-of(reverse)	7	7	7	20
Control	5	8	4	20
Switchboard	6	6	2	20
Same	4	7	7	20

equipment property with the property of other equipment. In Figure 4, the equipment "chlorine injection pump 1" has a "Pipe" relation with the property "concentration" of the equipment "aeration tank".

Strength of Relations

In order to select appropriate equipment under specific conditions, a viewpoint and a context dependent weight of a relation are introduced. The viewpoint specifies what kind of a relation is focused on and is set either by an occurred alarm or by users. The context dependent weight specifies the strength of the relations under the viewpoint, and the value of the weight is changed according to the viewpoint.

Table 1 shows an example of a relation's weight decided by a viewpoint. For viewpoints, there are "general" for a more general focus, "pipe" for focusing on a "Pipe" relation and focusing on a relation that is meaningful from the view of pipe connections, and "pipe only" for focusing only on pipe connections. It is possible to set a different weight for each direction
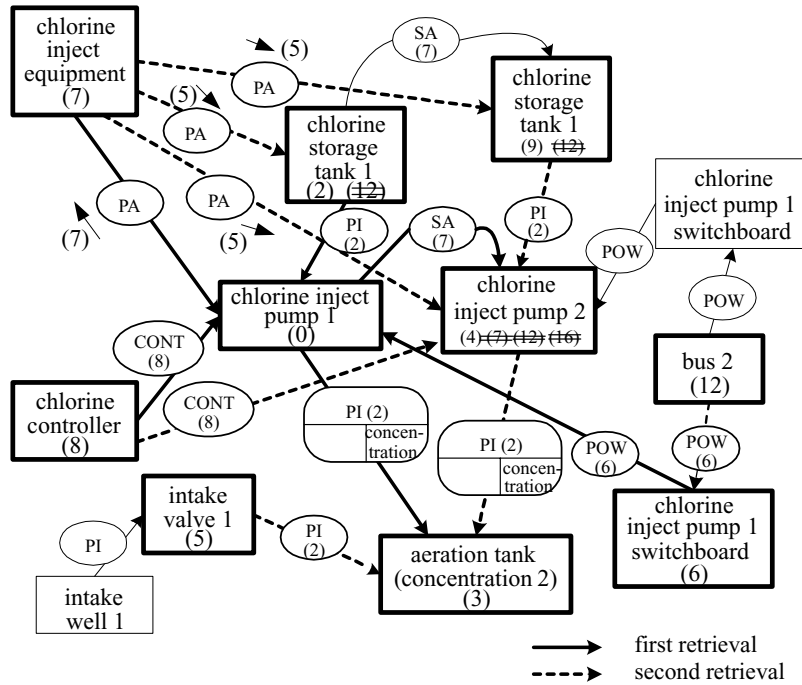
Figure 5: A snapshot of equipment selection

of the relations. The weight needs to be adjusted depending on the target domain of the system, the scale of the plant, and so on.

Moreover, a method for understanding the whole plant is provided. To achieve this, the class of equipment objects or any specific equipment object is set as a representative. The selection using a representative is called the outline selection. On the other hand, the selection using only weight is called the detailed selection.

In the next section, an algorithm using the graph structure and the weight is described.

4 Selection Algorithm

The selection algorithm is as follows: (i) Set the focused equipment in a graph structure as the start equipment. (ii) Collect equipment by traversing relations from the equipment. (iii) Calculate the priority of each piece of equipment. The priority is a sum of the weight of the traversed relations. In the case of outline selection, if the found equipment is a representative, the priority is raised. (iv) Repeat (ii) and (iii) until stop conditions are satisfied. Stop conditions are, for example, the number of traversed relations, when the priority value exceeds the predefined upper limit, and so on. (v) Sort the collected equipment in order of priority, and select equipment from the top of the sorted list.

In the following, the flow of the algorithm is described using Figure 5. Below, we use notation (E, A, P) for property A of equipment E that has priority P. "–" means that the property is not specified.

First, we use the equipment "chlorine injection pump 1" as the start equipment for the selection. The condition of the selection is assumed to be a detailed selection with the viewpoint "pipe". "(chlorine injection pump 1, –, 0)" is added to the selection candidate list.

Next, all of the relations connected to this equipment are collected and the priorities of the equipment, which are connected by the relations, are calculated using the weight of the relations. As a result, "(chlorine storage tank 1, –, 2)", "(aeration tank, concentration, 2)", "(chlorine injection facility, –, 7)", "(chlorine controller, –, 8)", "(chlorine injection pump 2, –, 7)", and "(chlorine pump 1 switchboard, –, 6)" are added to the selection candidate list.

Furthermore, all of the relations related to them are collected in the same way. If the same pair of equipment and property is already inserted in the list, the priority of the pair will be set lower. For example, the equipment "chlorine storage tank 1" has a relation with the equipment "chlorine injection facility". Since the weight of "A-part-of" relation in the reverse direction is 7, and the weight of "A-part-of" relation in the normal direction is 5, the priority of the "chlorine injection facility" becomes 12. However, "(chlorine storage tank 1, –, 2)" exists in the list, and therefore

Table 2: A result of selection

equipment	property	priority
chlorine injection pump 1	–	0
chlorine storage tank 1	–	2
aeration tank	concentration	2
aeration tank	–	2
chlorine injection pump 2	–	4
intake valve 1	–	5
chlorine storage tank 2	–	6
chlorine injection pump 1 switchboard	–	6
intake well 1	–	7
.....		

the priority of "chlorine storage tank 1" remains at 2.

Traversing continues even if the equipment properties differ. In this case, a constant value (in the example, 1) is added to the priority of the reached equipment. In Figure 5, the priority of the "aeration tank" is calculated as 3. Since the weight of the relation "Pipe" is 2 and the relation is qualified by the property "concentration", the priority of "aeration tank" is calculated by adding the weight and the constant value. Therefore, the priority of "intake valve 1" is calculated as 5.

Figure 5 gives a snapshot of the selection. The equipment displayed with a thick rectangle indicates already-collected equipment. The numbers in the parentheses show the priority of the equipment or the weight of the relation. The thick solid lines show the relations traversed the first time and the thick dashed lines show the relations retrieved the second time. In this example, the process is repeated, and the collection is stopped after the relations are followed a couple of times. Then, the selected candidates are sorted in order of priority. The result is shown in Table 2.

5 Related Works

As for visualization techniques to show a large amount of information, much research has been reported. In addition to fisheye approaches[2][3], Magic Lense filter[4] and Pad++[5] enable a very large area to be shown into a screen using a zooming or magnifying technique. A semi-transparent widget[6] attempts to show information by overlapping some contents. Though these approaches support PDAs, they require too much space for cellular phones to display. Moreover, the CPU power of current cellular phones is poor, and it is difficult for cellular phones to execute such a program.

In the case of web browsers, WEST[7], Power Browser [8], and Digestor[9] provide effective brows-

ing functionality for small screens. Making use of a proxy server and generate a suitable page for a small screen, these make it possible to show various web contents with a narrow band network. In addition, WEST also uses text reduction and flip zooming. These approaches use document structure to select the menu or contents. A SCADA mobile system must handle a lot of analog data, digital data, and their meaning (eg., equipment names). The data are homogeneous and there seems to be no clue to structuring from a Web document viewpoint.

Utilizing a narrow band network, a method of query preview was proposed. EOSDIS[10] achieved query preview to enable distributed database retrieval for network information systems. Query preview involves two phases: first it shows an overview of a database, such as a hit count of retrieval, by the first query, and then the user refines a query suitable to obtain a final retrieval result. The distributed database of EOSDIS is very large and is connected with a slow network, so it provides a preview stage to improve usability and reduce network access. It resembles our environment. The communication speed of cellular phones is very slow, and the database size of a large or medium scale plant is large. It is also possible to regard our method as a special case of query preview. In the preview stage, a cellular phone displays related equipment information, and operators can change the viewpoint and trigger equipment as the refinement stage.

An object-oriented modeling of supervised equipment is used in practical SCADA systems. SCOPE[11] is an object-oriented system architecture that achieves a flexible and maintenancable EMS (Energy Management System)/SCADA system, using models organized by equipment objects and their relations. SCOPE uses three relations in its model: physical and electrical connections of equipment, is-a relationships, and part-of relationships. These data can be applied to our method, adding other necessary relations such as conceptiual relationships and "switchboard" rela-

tions.

The graph structure of supervising equipment is regarded as a kind of semistructured database[12] from an information retrieval viewpoint, because our selection method is a case of information retrieval from a database that forms a graph structure. To provide a general flexible scheme, many studies attempt to design a query language and revise a retrieval technique in a semistructured database field. On the other hand, our approach stands on a more practical side than these approaches, and we aimed at a more optimized direct solution for each particular domain. If the scheme that can treat a dynamically changing weight of relations as a part of a semistructured database and its query language design is provided in the future, it will be applicable to our domain.

6 Conclusion

A method of constructing a user interface for a cellular phone by selecting equipment from a graph structure of supervised equipment is proposed in this paper. The purpose of the method is to give remote plant operators enough information to grasp a plant situation smoothly via cellular phone. The characteristics of this method are as follows: a graph structure composed of supervised equipment and their various relations, and a context dependent weight changed dynamically by viewpoints. An algorithm to select equipment from the graph structure is also described.

A prototype system has already been made. The server is built on a PC utilizing the Tomcat WWW server. Java Server Pages technology is also used to generate screen contents. A class library to get plant equipment and plant states is also provided. Evaluations of the method are in progress using actual plant data.

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