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# Human Computer Interaction through Consolidation and Visualization for Order Entry Systems

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*Abstract*—**In this paper, we propose a human computer interaction model through consolidation and visualization for order entry systems. This model makes effective use of the patient database and features 1) the consolidation of order data, 2) the visualization of the order data two or more contextual viewpoints, and 3) a new data entry and decision support function which consists of several data validation functions. The proposed model supports doctors' comprehension of order data by presenting the diversity, continuity, and regularity. This model has been incorporated into the order entry system and is now being run on an experimental basis. The effectiveness of this system was verified by the questionnaire survey from doctors and the analysis of consolidation.**

*Keywords*—**Human computer interaction, information consolidation, information visualization, order entry system**

## I. Introduction

Computerization in the medical field in Japan is being promoted by positive support from the public sector. The Ministry of Health and Welfare authorized the electronic storage of patient data in 1999, and among e-Japan strategic plans in 2001 submitted by the government's IT strategic board, computerization in the medical field was cited as an important development to be pursued.

Medical institutions are storing more and more historical data and working with transaction data from outpatients and inpatients. The demand on the work front for the computerization in the medical field involves the development of a more efficient way to run a hospital. The medical institutions also require the realization of an information system and a clinical support function capable of using the data stored in the patient record.

In Japan, many large-scale hospitals have introduced a order entry system. However, there are problems with order entry system.

1) Accuracy and preventing input errors in data input is urgently required, because a data-input error could result in malpractice [1][2].
2) Effective utilization methods of patient data, such as order history, are required.
3) Multiple views are required in order to satisfy various user needs [3].

In addition, Patients with lifestyle-related diseases require long-term care, as well as whole-body condition checks and continual medication. Although effective use of long-term order data and laboratory-test results are important in giving life style guidance to patients, we are not aware of an order entry system that contains doctor office system that focuses on such matters.

On the other hand, the information visualization technology is effective in efficiently showing a large amount of data diagrammatically, and in supporting users in understanding and manipulating the information[4]. The application known as LifeLines[5] is one example of the visualization of medical information.

Under these circumstances, we conducted research and development of a system that supports an efficient human computer interaction model. We propose a new model, which is based on information consolidation and visualization, improves order comprehension and order entry on consultation. This model has been incorporated into the order entry system and is now being run on an experimental basis.

## II. Methodology

### A. Human Computer Interaction Model

This paper proposes a human computer interaction model for the doctor office system which is one of the department subsystems of the order entry system. This model, which utilizes patient's order history effectively, achieves clinical support functions. For example, this model is capable of attaining contextual comprehension of order data. This model consists of the three components: information extraction, information visualization and data entry, as shown in Fig. 1. The information extraction component consolidates chronological order data and constructs a content-oriented data structure. The information visualization component supports three different kinds of views. The data entry component has new data entry methods and a data validation function.

### B. Information Extraction Component

The information extraction component, as shown in Fig.2, derives two views from chronological order data. These views are a Diversity-oriented View that represents contents characteristics and a Progress-oriented View that represents time characteristics.

The Diversity-oriented View represents a diverse range of order data. The order data, such as prescription order or laboratory-test order, are made based largely on the doctor's experience and knowledge, and the doctor orders a number of order items at the same time. Therefore, the extraction process of Diversity-oriented data proceeds as follows: 1) grouping drug items and laboratory-test items which are ordered at the same time, 2) ignoring the data which are highly dependent on the dates of the consultations, 3) consolidating the groups which consist of the same order contents. This process ignores the basic consultation data such as date, treatment department, and doctor name, as well as detailed implementation methods such as the medication periods. Thus, the Diversity-oriented data, which are extracted from the order data, have no redundancies in terms of contents and are highly independent of the dates of consultation.

The Progress-oriented View represents the cross-relationships of order data (such as the continuity and regularity of data) that exist among the long-term order data. This view is a symbolized and reduced data structure of chronological order data. The symbolization replaces each order contents with the ID of Diversity-oriented data.

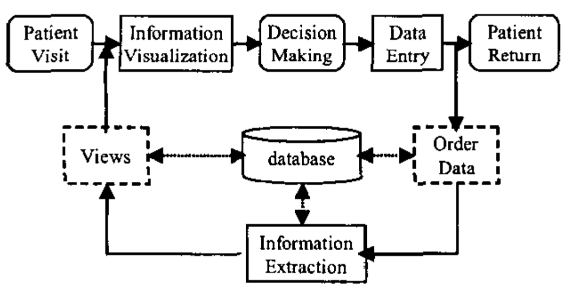


Fig. 1 Human computer interaction model

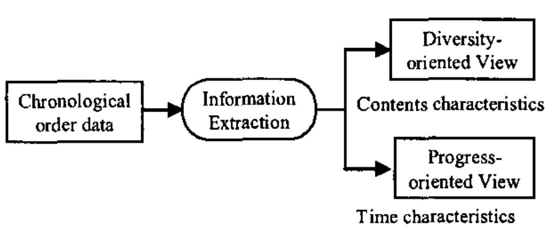


Fig. 2 Information extraction function derives two views from order data

*C. Information Visualization Component*

We propose a new viewer to display the order data on the screen. It is called the "SAKURA-viewer". This viewer has the ability to detect order patterns and to clarify the order history, and facilitates the operator to comprehend the continuity and regularity of order data. This effectiveness cannot easily be obtained from the data on paper card based patient records or from the presentation given by a system that inherits the representation format of the paper card based patient records. This viewer supports two different kinds of windows, named Diversity Window and Progress Windows.

The Diversity Window presents a diversity of order contents such as singly issued orders, which tend to be buried among continually issued orders, and slight variations in the applied medications and their dosage. The display unit of this window is the Diversity-oriented data. Thus, this window supports accurate comprehension of the order contents by doctors. It is also useful for avoiding duplicated and contraindicative orders in consultation.

The Progress Window presents the continuity and regularity of the order data. The display unit of this window is the Progress-oriented data. It is useful for precluding the omission of checkup items as well as detecting long-term repeated orders in consultation. Moreover, simultaneous visualization using the Diversity Window and the Progress Window supports the contextual comprehension of the order contents as illustrated in Fig.3[6].

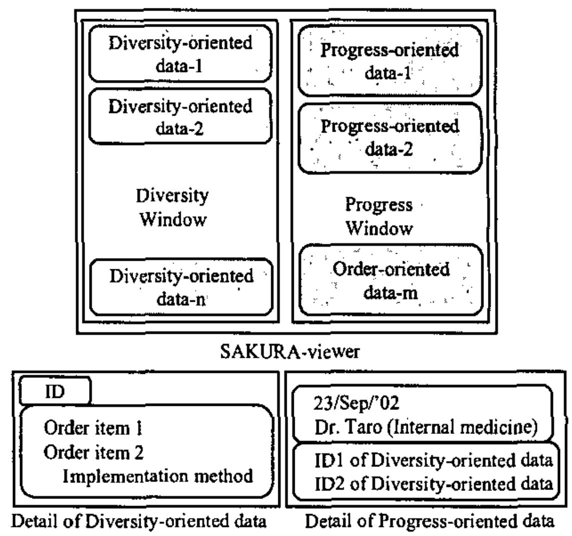


Fig. 3 SAKURA-viewer has Diversity Window and Progress Window. Diversity-oriented data consists of data ID, order items and implementation method. Progress-oriented data consists of the consultation basic data and the IDs of Diversity-oriented data.

*D. Data Entry Component*

The data entry component provides data entry and decision support functions. This component supports several data entry methods. The SAKURA-viewer integrates the data-input space with the data-output space. This integration offers new entry methods, which directly manipulate the

Diversity-oriented data and the Progress-oriented data, and thus increases the efficiency and accuracy in data entry. These input methods facilitate the patient dependent data to be used as the input data. These also allow the doctor to use hospital and personal order sets.

The decision support functions, such as duplicate order checks, range checks of entry data, patient drug allergy checks, default doses, are also implemented in this component.

## III. APPLICATION DESCRIPTION

### A. System Architecture

We have developed order entry system which included the proposed human computer interaction model. This system is a 3-tier structure, consisting of the database server, the communication server, and the user interface PC layers. The database server specializes in serving as a Data Base Management System (DBMS). We used ORACLE8 as the DBMS, and Visual Basic as the description language for each department's system, such as reception or appointment-making system. The communication server communicates with laboratory test system and other medical institutions. The user interface PC runs the department systems such as doctor office system and appointment system.

### B. Doctor's Office System

We developed a doctor office system that adopts the SAKURA-viewer. Using this system, as shown in Fig. 4, the doctor enters prescription, laboratory-test and physical-test orders. This system displays both the SAKURA-viewer that displays the order history and the order data that is to be created for the current day on the same screen, so that the doctor and medical staff can easily understand and analyze the past orders and the orders for the current day seamlessly. The doctor also enters life style guidance orders and uses laboratory test result viewer.

The medication data in a prescription order serves various purposes including the follows:

1) Prescribes continually over an extended period, for example, a lifestyle-related disease.
2) Prescribes over a certain period of time for the treatment of a particular disease.
3) Prescribes a one-time item such as an antipyretic.

The Diversity-oriented Window is suitable to represent these various types of drug data without omission.

On the other hand, the laboratory-test orders have various purposes as follows: 1) the test items exist singly for the screening at the patient's first visit, 2) the test items that are used to determine the conditions of patients with, for example, lifestyle-related diseases. Since the periods of checkups are not fixed, control of the checkup intervals is important in fully comprehending patients' conditions. The Progress-oriented Window, that displays no order items, emphasizes the consultation date. Thus, this system supports rapid comprehension, whereby visualizing the existence of regularly conducted laboratory-tests and their periods efficiency.

One of the major purposes of the treatment for a lifestyle related disease is to prevent the complication of and maintain the stable condition of the disease. Consequently, it is important to prevent omissions of laboratory-test items. In addition, the doctor requires the laboratory-test patterns to be displayed assorted by patient, and needs to be aware of the type and dosing period of the drugs that are dosed to other diseases to preclude adverse drug event. These requirements are supported by consolidation and visualization of SAKURA-viewer.

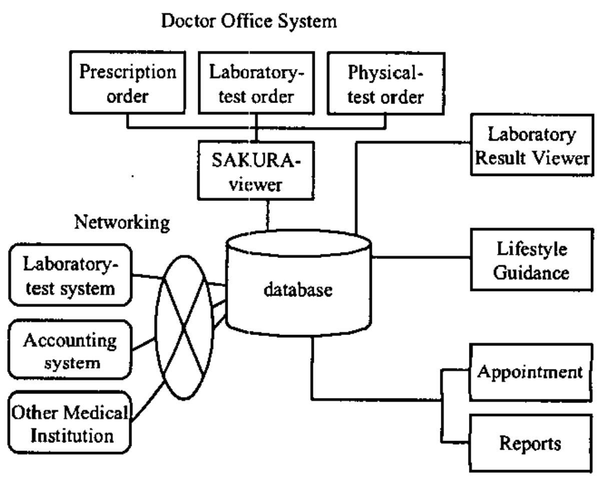


Fig. 4 System architecture of order entry system

TABLE I
SYSTEM OPERATING CONDITIONS

| | System A | System B |
|---|---|---|
| Total number of prescription orders | 474,422 | 75,299 |
| Total number of laboratory orders | N/A | 13,712 |
| Total number of laboratory results | N/A | 84,319 |
| Total number of patients | 24,826 | 2,432 |
| Total number of doctors using the system | 60 | 10 |
| Total number of user interface PCs | 28 | 8 |
| Started date of data storing | Sep/01/'98 | Sep/01/'99 |

### C. Operating Conditions

This system is being run at a medium-sized medical institution (System A) that accommodates 13 consultation rooms for 8 treatment departments, including internal medicine, surgery, pediatrics, and dermatology, which is visited by approximately 500 outpatients every day; and a small medical institution (System B) that accommodates 4 consultation rooms for one treatment department, internal medicine, which is visited by approximately 150 outpatients with chronic diseases every day. Table 1 shows the operating conditions of those systems as of January 31, 2003.

## IV. Evaluation

### A. Questionnaire Survey

In order to analyze this system functions, we conducted a questionnaire survey in November 2001. We asked seven doctors who were using System B to rate the system on a scale of "5" (highest) to "1" (lowest). As for the human computer interaction model that was based on the consolidation and visualization of order data, the questionnaire survey of users showed that they highly evaluated the support function to comprehend order contents and order history. Accordingly, we concluded that this system was effective.

For the prescription orders, both the information comprehension function and planning support functions were highly evaluated, with a small statistical deviation in evaluation. The usefulness of the function to display the medications list and of the prescription history was confirmed. Moreover, some doctors had a favorable impression that this system enabled them to search for the appropriate medications easily from patients' ambiguous statements such as "the cold medicine I took last time was effective." Thus, the high practicability and validity of the human computer interaction model and visualization of the prescription order were confirmed.

For the laboratory-test orders, the function to display the laboratory-test history was most highly evaluated. The fact that doctors could easily comprehend the regularity of the laboratory-tests was considered the reason for such a high approval rate. The support function for creating the laboratory-test order data also received appreciative recognition.

### B. Analysis of the Consolidation Effects

The method of presenting order data discussed in this paper eliminates data redundancy by integrating the data contents. From the study of the operating conditions of System B conducted from April through December 2002, we analyzed the effects of redundancy elimination. By analyzing prescription orders, we found that a total of 15,942 prescription orders were issued to 1,936 patients during these eight months. An observation of the details of the prescription orders revealed that 80,729 drug items constituted 59,141 order contents in total. By consolidating them for each patient, we found that 9,649 types of the Diversity-oriented data were extracted. We then calculated the average number of items per patient by dividing the number of items by the number of applicable patients, and found that 8.2 prescription orders occurred for each patient during these eight months and that 30.5 order contents were constituted and consolidated in 5.0 types of the Diversity-oriented data. Similarly, from the analysis of the laboratory-test orders, we found that there were 3.2 laboratory-test orders on average and that 4.8 order contents were constituted and consolidated in 3.5 types of the Diversity-oriented data.

An analysis of the consolidation effects also revealed that most of the order data for each patients share the same order contents. This fact confirms the necessity of avoiding redundancies by consolidating order data.

## V. Conclusion

In this paper, we proposed and described a system that realized a human computer interaction model that achieves consolidation and visualization of order data. The proposed model supports doctors' comprehension of order data by presenting the diversity, continuity, and regularity that are inherent in the interrelationships of accumulated order data. This model reduces doctors' workload in the reading and comprehension of patient records and contributes to the computerization and service improvement of day-to-day medical care such as the supervision of patients with lifestyle-related diseases. The validity of the system was verified by the questionnaire survey of users and by the analysis of the consolidation effects.

We hope that, in the future, we can further research and develop a method of conveniently combining the visualization function for order data with that for laboratory-test result and guidance data, aiming at the realization of a comprehensive visualization method for medical information.

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