UNDERGRADUATE REPORT

REU Report: Development of a Global Information Exchange Database System for the Machinability Evaluation of Dental Ceramics

by Hironobu Katoh, Bing Chen, Guangming Zhang
Advisor: Guangming Zhang

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ABSTRACT

Aesthetic character, high strength, chemical durability, and bio-compatibility make dental ceramics ideal ingredients for fabricating dental restoratives. However, the inherent brittleness of ceramics poses a challenge to the machining of ceramic restoratives. With the introduction of Dental CAD/CAM system, machinability evaluation is necessary to successfully fabricate dental ceramics for commercial use.

This paper presents a unique approach to conduct the systematic experimental research for the machinability of dental ceramics. A database management system is employed to perform the systematic data management and manipulation function. This database engine is then connected to the World Wide Web to take advantage of the information infrastructure provided by it. Through user-friendly interface, this online database system provides guidance for the experiment design, data collection and data analysis. With the connection of the database to the World Wide Web, interactive web page can be generated to facilitate the information exchange and dissemination. This method utilizes new technologies to allow users to swiftly share information to anyone around the world.

Key words: Database, On-line database, Dental ceramics

1. INTRODUCTION

As the information technology advances and the world becomes smaller, the importance of communication and information exchange increases. This fact applies especially in scientific and engineering fields. Usually, there are several professors and researchers conducting similar research around the world. These different individuals might be competing with each other, but many times they cooperate by forming teams. In the later case, there must be a method of communication, a method for exchanging valuable experiment data to anyone and everyone on the same team.

There are two main objectives that must be accomplished by such a method. One is to organize the experimental data so everyone can understand it with minimum hassle. Second is to deliver the experimental data quickly and efficiently. The first can be accomplished by using the computer technology to create a standardized database for the particular experiment.

For the second, there are a couple of options. Mailing a hardcopy or a computer diskette with data is plausible but not practical. Attaching files via e-mail is another method, but it can be tedious. There could also be formatting problems where files can not be read by particular programs or operating systems. Fortunately, the Internet is not limited to the popular e-mail. The World Wide Web is another popular tool which many people are now familiar with.

In this paper, a new approach that utilizes online database technology to facilitate the scientific research is presented. The research project studied here is the machinability evaluation of dental ceramics. Due to the difficulties related to the machining of ceramics, machinability evaluation is critical for the successful application of dental ceramics with the dental CAD/CAM systems. The machinability evaluation should be able to provide sufficient comparable data of different types of dental ceramics to help the material selection and machining process setup for dental CAD/CAM system and also to help the research and development of new materials. This systematic research project needs plentiful data process and analysis and cooperation of peoples from different research groups, dental community and manufacturers. With its powerful data processing and information exchanging capabilities, database system and the World Wide Web technologies can be fully utilized to perform the information management, exchange and dissemination for this machinability evaluation system.

2. SYSTEM ARCHITECTURE AND SYSTEM ACCESS METHODOLOGY

A Web-based database system housing experiment and analysis data regarding the machinability evaluation of dental ceramics was selected as the system architecture. The database was designed to perform the data management and access service. Through the World Wide Web, information stored in the database engine becomes accessible to authenticated users throughout the world to promote profound cooperation and information sharing among researchers located geographically far away from each other. The online database system created here serves not only as a warehouse for experimental data, but also as a medium to promote efficient data organization and data analysis through a user-friendly Web interface. Figure 1 illustrates the system architecture of the on-line database system.

Several advantages exist to support this system architecture. First, the utilization of Internet and THE World Wide Web provides the easiest and cheapest way for worldwide information sharing and exchange. This system is readily accessible to users who have the

connection to the Internet without the installation of any proprietary application software on the client computer, and this communication is independent to the hardware and operation system used in the client side. User-friendly interface provided by the World Wide Web can greatly enhance the information presentation and understanding. At the same time, database engine can provide powerful and reliable data management and access service. Since data management is centralized on the database server, data integrity and security can be better addressed. With the help of dynamic web page generation, information can be organized with respect to the user request to provide better data access service to meet the user's information requirement.

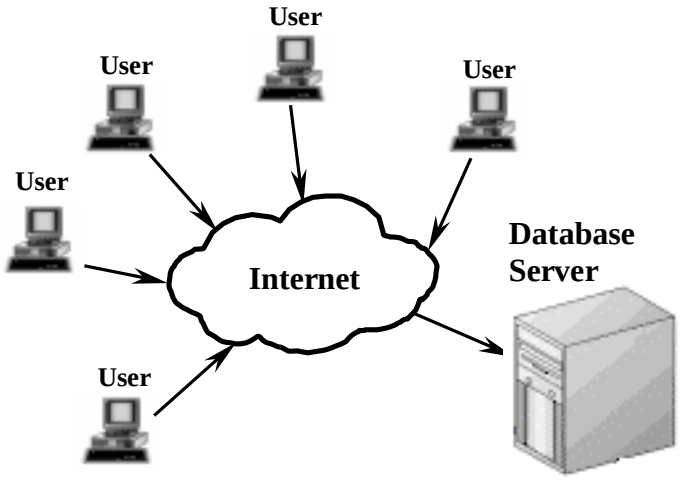

Figure 1. System architecture

3. CONNECTION BETWEEN THE DATABASE AND THE WORLD WIDE WEB

Connecting the database to the World Wide Web is the key component for implementing this information system. Currently, online database development can be approached with three different methods. The first method, commonly used by large organizations, is to create Web-enabled applications running inside a browser using plug-in or ActiveX components. The second method uses HTML combined with either of the two previous components. Both of these methods require the user to install plug-ins on their browser, resulting in fatter clients. The third method involves linking a database to the World Wide Web using pure HTML to design the project's front-end interface. A software package provides the connection between the Web server and the actual database residing on the web server. The result is a thin client, since users only need a Web browser to view the page. Common Gateway Interface (CGI) links the Web server to the database. This program can be executed in real-time to respond to the user's database access request and to output. This last method was utilized for this study.

Many computer languages can be used to write CGI script to access a database. Different development tools provide different functions and connectivity, but the price is also different. Most of them range in price from sever hundred to over $2000. These tools represent a wide

spectrum of approaches to web-based database programming, and some of them may be more suitable than others depending on the sought after functionality. In this study, Cold Fusion, a web-based database development tool affordable to most small and median size businesses or research groups, is chosen for the development of the on-line database system for the machinability evaluation system of dental ceramics.

4. DATABASE DESIGN

Relational database system is a database model that is used commonly. There are a lot of different relational database system products commercially available. Although all of them can provide basic database management functions and support Structured Query Language (SQL), they are different from application range, feature, hardware and software requirement and price. Some, such as Oracle, Informix, and Sybase can provide enterprise-level solutions but cost more than $10,000. Others, such as Microsoft Access, dBase, and Microsoft FoxPro, may cost only several hundreds of dollars and be able to provide a small business solutions. In this study, Microsoft Access was chosen as the database engine to support the on-line database system. As a component Microsoft Office package, Microsoft Access is definitely one of the most affordable relational database system.

At the core of the relational model is the concept of a table (also called a relation) in which all data is stored. Each table is made up of records (horizontal rows also known as tuples) and fields (vertical columns also known as attributes). Different tables are related to each other through key fields. The data represented in the machinability evaluation system is organized into several tables. Figure 2 shows the relationship among them.

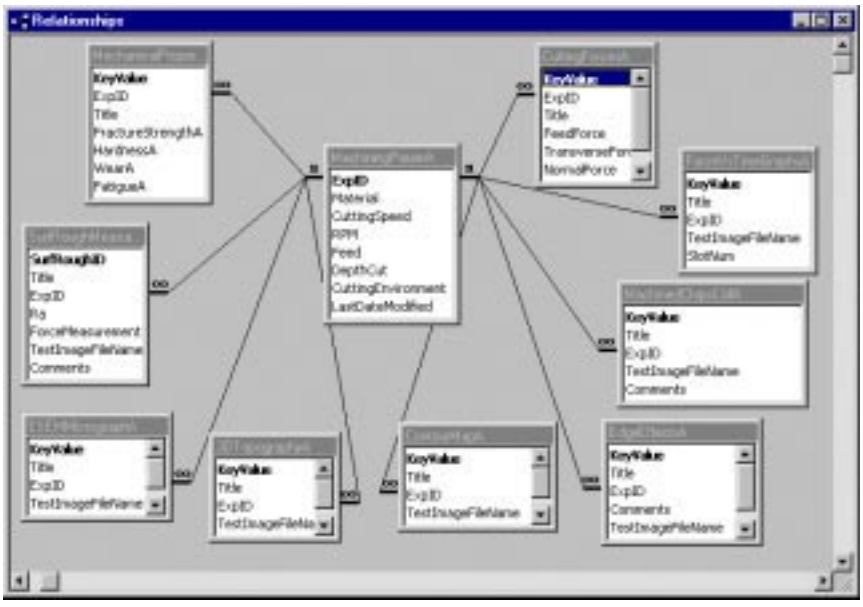

Figure 2. Database structure for the machinability evalution system

5. SYSTEM IMPLEMENTATION

The actual system implementation should be aimed to provide the expected system function. This on-line database system serves the machinability evaluation system for the information management, processing, exchange and dissemination. It can help the experiment design, experiment data update, experiment data review and data analysis. Figure 3 illustrates a simple system flow chart.

5.1 Experiment design function

As a valuable statistical tool, experiment design method is helpful to filter the noise out of the experimental data and obtain useful and unbiased conclusion from limited experiment runs. For the machinability evaluation, experiments will be performed to measure the effects of several machining parameters on the system responses. Based on this purpose, factorial experimental design method is chosen, since factorial design, especially two-level factorial design, are extremely useful for this kind of investigation. This design method is economical and easy to use and can provide a great deal of valuable information.

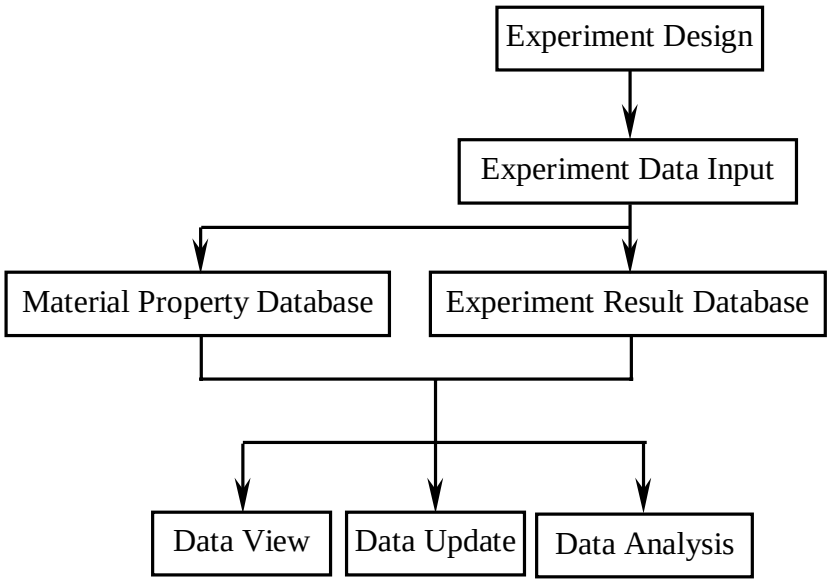

Figure 3. A simple system flow chart

Table-1 is a design matrix illustrating a two-level factorial experiment design. When using this method, the experimenter assigns two different levels or values to each variable. For quantitative variables, a high level, denoted by "+", and a low level, denoted by "–", are assigned. For qualitative variable, such as different catalysts, the two different values may be represented by symbols such as "A" and "B". So for an n-variable full factorial experiment design, there are a total of 2^n runs. The cube in figure 4 represents the two-level factorial experiment design in a more intuitive way.

Table 5-1 Matrix representation of 3-variable two-level factorial experiment design

Experiment No.	Variable 1	Variable 2	Variable 3
1	–1	–1	–1
2	+1	–1	–1
3	–1	+1	–1
4	+1	+1	–1
5	–1	–1	+1
6	+1	–1	+1
7	–1	+1	+1
8	+1	+1	+1

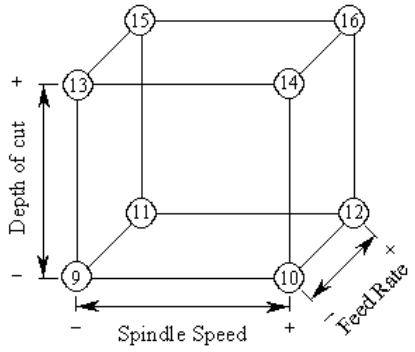

Figure 4. Geometrical representation of the design matrix

Figure 5 illustrates a page created to help the factorial experiment design. After specifying the material name, cutting environment, and the rest of the variables, server-side script will perform the experiment design and will output the setup of different experiments.

Figure 5. Experiment design page

5.2 Experiment data input and update

Experiment input page is designed for the experiment data input and update. Using this page, measured system results can be input into the database. Experiment data update can also be performed using this page. Figure 6 illustrates the experiment data input and update page. There are two special features added into this page to enhance its functionality. First, client-side script using JavaScript is used to check the integrity of the data input. Putting this task at the client side reduces the pressure on the server's CPU. Second, file upload function is provides through this page. This enables users to upload ESEM pictures to the server remotely, enhancing the information exchange.

Figure 6. Experiment data input and update page

5.3 Data view

Data view is an important function since most of the users of the on-line database system are viewing the experiment results instead of modifying it. A well-designed data view page will help the presentation of its information. Figure 7 illustrates the data display page, which displays the results of the experiment, selected by the user.

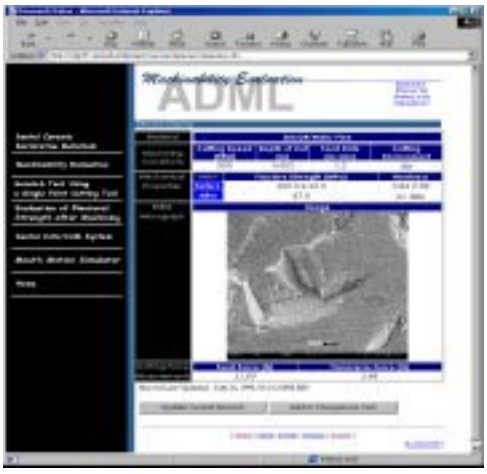

Figure 7. Data display page

Since it is possible that a data collected for one experiment is different from others, some experiments may miss some data entries and some of them may have additional data fields. This non-homogeneous feature has been taken into account when design the data display page of this on-line database system. According to the user's request for information, the data display page dynamically creates a table to show the information currently exists in the database for the particular experiment. Blank fields are filtered out and only existing data fields appear on the display page. This feature keeps the display page from becoming cluttered with unnecessary or unused spaces/blanks. Thus, it allows the developer to customize the data presentation format for different experiments.

Another feature needs to mention here is the display of micrographs. In order to present user a better view and investigation of the microstructure, online image enlargement function is provided to allow user to enlarge the micrographs and get a better view of it.

5.4 Data analysis

Data analysis function provided by this on-line database system includes the derivation of the empirical model and data comparison analysis.

Generally, data have no meaning in them, except in relation to a conceptual model of the phenomenon studied. Sometimes, if the phenomenon under study is well understood, it is possible, from theoretical considerations to write down a plausible functional form expressed in mathematical equation to describe the phenomenon. This equation is then called theoretical model. But most of the time, the mechanism underlying a process or phenomenon is not

understood sufficiently well, or is too complicated, to allow an exact model to be derived from theory. In such circumstances an empirical model may be useful, particularly if it is desired to approximate the response only over limited ranges of the variables. Considering the machinability evaluation system studied here, an empirical model is the best candidate to exploit the relations between the system input and system response because the machining system is too complicated to be expressed using a theoretical model.

Built-in function of the on-line database system will derive the empirical model and present the result to the user by performing the necessary data manipulations. With this function, experimenter is released from the trivial mathematical calculation work and can concentrate on the in-depth interpret of the data and model.

Figure 8 illustrates two methods employed to present the derived empirical model to users. One is through mathematical equation shown right below the letters "ADML." The other is through a pie chart shown right below the equation. The pie chart illustrates the magnitude of different effects, including the main effect of each factor and the interactive effects, to the system output. With the conjunction of the mathematical equation, this pie chart explicitly shows which effect has the most prominent influence on the system output, and helps relate between the system response and the system input.

Besides the investigation of the machinability of each individual material, the effect of machining different ceramic materials under the same machining conditions is also investigated, since many different ceramic materials are under the study. This comparative study helps researchers relate the machinability to the material microstructure to understand the effects of the microstructure on the machinability. The data comparison page is designed to help the comparative study of the system response of different material toward the same machining condition, or the system response of the same material under different machining condition, or the system response of any experiments selected by the user. Figure 9 shows the comparative study of the fracture strength after machining among three different materials: Dicor/MGC-Fine, Dicor/MGC-Medium and Dicor/MGC-Coarse, under the same machining condition. This comparative study page explicitly tells us that when under the same machining condition described in the page, after machining, the fracture strength of Dicor/MGC-Coarse is the highest among the threes materials, although its fracture strength before machining is the lowest. This comparative study provides visual aid to reveal important phenomenon to the user.

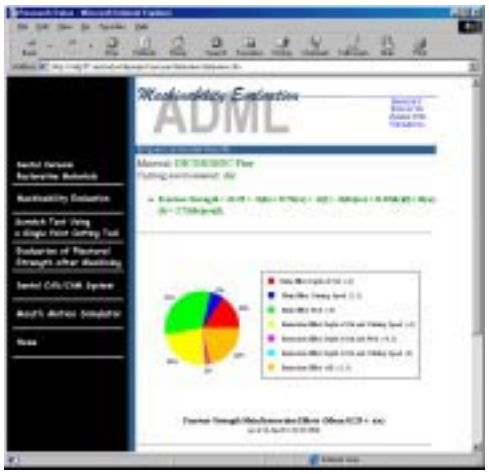

Figure 8. Empirical model derived by the system

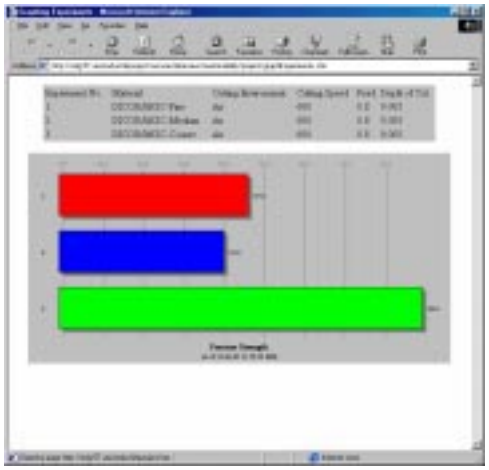

Figure 9. Comparative study page

5.5 Material property database

Material property database is an important component of this machinability evaluation system. This database has the property data sheet of those materials under the investigation. Data in the material property database represents the property of the material before machining operation. They provide a reference for the research of the material machinability. Microstructure plays an important role in the ceramic machining process but it is often hard to be quantified. Therefore, a micrograph of the material microstructure is also presented to facilitate the research of the relation between microstructure and machinability. The user can dynamically enlarge the micrographs for a better view. Dynamic data display is also employed to create data display table for each material on the fly. Figure 10 illustrates the material property display page.

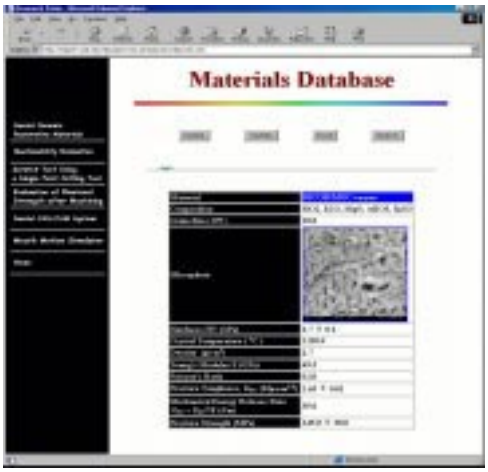

Figure 10. Material property display page

5.6 System access control

Since the on-line database system is connected to the World Wide Web, it is open to all the people who have the access to the Internet. This publicity brings out the issue of protection of the sensitive data and results, as some of the findings should not be released to the people out of the research projects before its publication.

System access control is employed with the development of the system to protect the intellectual property of the research group. In this study, the database engine is involved to provide the system access control through user name and password authentication. A table containing the valid user name and password information is created. Every time, when a user tries to enter the protected area of the system, the assigned user name and password must be provided for authentication. Failed to pass authentication will result in the rejection of the service request.

Even for the authorized system users, system database write rights should also be controlled. Otherwise, the whole system will be crashed by careless or malicious modification. User read and write access rights is also saved in the same table with user name and password and any attempts to modify system database will be subjected authentication. These system access control policies not only protects the unauthenticated visit of sensitive data, but also maintain the integrity of the database.

6. CONCLUSIONS

This paper presents the application of computer information technologies, mainly database system and the World Wide Web technologies, in scientific research area. Utilization of the on-line database system for scientific investigation through experiment data management,

data manipulation, data presentation and data analysis is efficient and effective application of the World Wide Web.

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