AN INTEGRATED CLINICAL TRIALS SYSTEM UTILIZING CLIENT SERVER AND GRAPHICAL USER INTERFACE TECHNOLOGY

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ABSTRACT

Motivated by the desire to better manage an ever increasing volume of information and to reduce the length of time required to introduce new drugs around the world, the pharmaceutical industry and regulatory agencies such as the U.S. Food and Drug Administration have sought to facilitate the drug development and approval processes through innovative uses of computer technology. One such effort that has received great attention is the computer assisted NDA or CANDA and its cousin for biologicals the computer assisted PLA or CAPLA.

The first CANDA’s were created with much effort, and at great expense, after the paper NDA’s had been filed. From these early experiments, it became evident that if CANDA’s were to ever become routinely used throughout the industry by both large and small companies, their development would need to be simplified and to begin earlier in the drug development process. Medical reviewers at regulatory agencies have frequently commented that for a system to be useful as a CANDA, it should also be beneficial for in-house use. While recent advances in computer technology now permit the construction of sophisticated systems which remain relatively simple to use, in order to maintain data integrity, it is essential that data tables do not require transformation or restructuring by the end user. Hence ideally, the development of a CANDA should begin at the time of study definition and data entry.

With these goals in mind, MAJARO has explored ways of developing systems which seamlessly integrate data entry and in-house medical review, so as to facilitate CANDA development. This paper discusses CLINACCESS™, an integrated clinical trials system developed with SAS® software, that combines the data entry and data management capabilities of traditional clinical information systems, with clinical data review features that permit monitors, CRA’s, managers, and other members of the clinical staff to monitor the progress and quality of ongoing clinical trials. It achieves its ease of use through a graphical user interface that incorporates pull-down menus, scroll bars, dialog boxes, radio buttons, and a mouse. Initially developed for use on PC compatibles, the code has been written to permit easy porting to other computer platforms and exploitation of client-server technology.

THE DRUG APPROVAL PROCESS

Unlike most other industries, companies in the pharmaceutical and biotechnology industry must first obtain government approval before they can bring a new product to the market. The process of obtaining government approval can often be long and complicated. In the United States, the company must first use the proposed drug in animals to show that there are no gross toxic effects. With this knowledge, the sponsoring company obtains an IND (Investigational New Drug) from the Food and Drug Administration (FDA). An IND permits the sponsor to ship the drug across interstate lines for tests in humans.

Once an IND is obtained, the three pre-marketing phases of clinical research begin. Phase I typically starts by using small single doses in healthy human volunteers in order to look for toxic effects in man. As evidence of safety is accumulated, dosages are increased to therapeutic levels. In Phase II, the drug is tried in human volunteers with the targeted disease. Sample sizes are small, and information is gathered concerning the appropriate dose and regimen to use to obtain a therapeutic effect. Once sufficient information is gathered and hypotheses about the drug’s efficacy in various indications have been formulated, large scale Phase III testing in human volunteers begins.

The research process can take five or more years. Throughout the process additional information is gathered concerning the safety of the drug in both humans and animals; the stability of the drug (how long it can remain on the shelf without degrading); the pharmacokinetics of the drug, i.e., how it is...
metabolized in humans; and the ability of the company to manufacture the drug in production quantities.

When all the required research is completed, the drug company submits its information to the FDA and makes a formal request for permission to market the drug in specified diseases. This registration process is known as a New Drug Application or NDA in the United States. An NDA is frequently between 200 and 400 volumes long or more than one hundred thousand pages. Although information from many scientific disciplines is presented, frequently the largest single portion of the NDA is the clinical section. The FDA reviews the NDA and can take three actions: approve the drug for all or some of the indications; not approve the drug; or request more information be gathered. The review process frequently takes another two or more years.

Although the details differ, the drug approval process is conceptually the same in other countries. Experimental information is gathered according to the requirements of the particular country until sufficient information is gathered to submit the drug for approval to a governmental regulatory agency.

CANDAS

Spurred on by the desire to better manage an ever increasing volume of information and to reduce the length of time required to introduce new drugs around the world, the pharmaceutical industry and regulatory agencies such as the U.S. Food and Drug Administration have sought to facilitate the drug development and approval processes through innovative uses of computer technology. One such effort that has received great attention is the computer assisted NDA or CANDA and its cousin for biologicals the computer assisted PLA or CAPLA. The features and technology utilized by CANDA's have varied greatly. Nonetheless, three general areas have emerged: a data portion, with the ability to query and analyze an on-line database; an image portion, that presents electronic images of case report forms; and a text portion, that displays and frequently permits the manipulation of the text from the paper NDA submission.

Experimentation with CANDA's began in 1986. The earliest CANDA's were developed after the paper NDA's had been submitted. Because of this, they involved tremendous effort and frequently great expense. As the use of CANDA's increased, it became clear that similar tools would be useful for review by in-house medical and regulatory personnel. Recent advances in computer technology have made it possible to develop systems capable of performing complex tasks while requiring minimal knowledge on the part of the user. Nonetheless, because of the potential for compromising the integrity of the data, transformation and restructuring of data tables are best left to computer professionals. Thus, for in-house review systems to become practical, the data must be available in a form that does not require transformation. If such systems are to be used while studies are in progress, the data storage and retrieval structures used for data entry must already be amenable to clinical data review. With these objectives in mind, MAJARO InfoSystems has explored ways of developing systems which seamlessly integrate data entry and in-house medical review, so as to facilitate CANDA development. Our first product is the CLINACCESS™ clinical trials system.

CLINACCESS™

CLINACCESS™ is an integrated clinical trials system that combines the data entry and data management capabilities of traditional clinical information systems, with clinical data review features that permit monitors, CRA's, managers, and other members of the clinical staff to monitor the progress and quality of ongoing clinical trials. Originally written in Version 5.18 SAS/AF® software for use on IBM mainframes (Rosenberg 1989a and 1989b), CLINACCESS has been ported to Version 6 SAS software and is available on desktop platforms.

CLINACCESS 2.5 is a full featured data entry system containing all the capabilities required in a pharmaceutical environment: an integrated data dictionary to facilitate new study definition and pooling of data, single and double-key data entry, customization of data entry screens to resemble Case Report Forms, interactive and batch edit checks, support for a thesaurus such as COSTART, and a full audit trail facility which records all changes and the reason for the changes. However, unlike similar systems, CLINACCESS not only captures data, but delivers information to users on the clinical staff such as medical monitors, clinical research associates, and managers. This information permits the clinical staff to track the progress of ongoing clinical trials and use this information to plan future studies. Designed for the 90's, CLINACCESS has a
CUNAccess™ 2.5 Features
- Graphical user interface (GUI) with pull-down menus, dialog boxes, scroll bars, radio buttons, and check boxes. Use of a mouse is supported but not required.
- Extensive context sensitive help system
- On-line tutorial to aid the new or infrequent user
- Clinical Questions Catalog (data dictionary) ensures uniformity of variables across studies, facilitating the pooling of information

CUNAccess™ 2.5 Capabilities
- Study Definition
  - Restricted to Database Administrator
  - Structure new tables from Clinical Questions Catalog or from previous studies
  - Data entry screens can be customized to resemble Case Report Forms
- Post-processing facility to perform edit checks or restructure data
- Data dictionary reports
- Manage study libraries
- Data Entry
  - Single or double-key entry
  - Interactive range, value, and/or cross-field checks
  - Batch edit checks through the post-processing facility.
  - Can be used with drug or adverse events thesaurus (such as COSTART)
  - Full audit trail facility captures changes made to the database and reasons for the changes.
- Browse data
  - View and query data in case report form format
  - View data in table format
- Queries
  - Concatenate and merge tables
  - Boolean logic queries and subsetting
  - Select subset of variables from a list
  - Compute new variables from existing variables
  - Retain temporary tables
- Graphics
  - Printer plots and high resolution color graphics
  - Horizontal and vertical bar charts, block charts, pie charts, scatter diagrams, line charts (requires SAS/GRAPH®)
- Descriptive Statistics
  - Commonly used statistics for quantitative data: mean, standard deviation, variance, standard error of the mean, minimum, maximum, sample size, range, sum, coefficient of variation
  - Full statistics for quantitative data: useful for visualizing and summarizing the shape of the distribution
  - Cross-tabulations: frequencies and percentages for categorical data. Chi-square and Fisher's exact tests.
- Report Generation
  - Customized data listings with optional column sums
  - Hierarchical tables of descriptive statistics

An Example
These concepts will be illustrated by an example of data entry and clinical data review.

Data Entry Example
CUNAccess is designed as an integrated clinical information system, which is distinguished from other such systems by its graphical user interface (GUI), ease of use, and strong clinical data review component.

The data entry component of CUNAccess 2.5 consists of study definition, data entry with on-line edit checking, data verification, post-entry data validation, and audit trails.

One or more users are identified to CUNAccess as Database Administrators (DBA). To protect the integrity of the data, only the DBA's have access to a subsystem of CUNAccess which is used to: create study libraries, define new studies to the system, manage existing studies, verify and validate data, update the Clinical Questions Catalog, and add new users to the system. Similarly, only those users specifically granted data entry and verification privileges by the DBA are permitted to enter or modify data. All other users may view but not modify the database.

To define a new study to the system, the DBA first creates a study library. Then one or more tables are created to hold the data. CUNAccess was specifically designed to facilitate the pharmaceutical industry's need to create data entry applications...
rapidly. To meet this need, tables can be defined in two ways. First, the table can be created from the Clinical Questions Catalog by merely selecting the names of variables to be included from a list. All defining information such as variable type, length, label, format, and informat are automatically included. To provide flexibility while enforcing standardization, the label, informat, and format may be customized to the study, while the name, type, and length of the variable are fixed.

The second method recognizes the fact that pharmaceutical firms frequently run similar trials on a compound. To accommodate this, a table may be created from a previous study which is similar to the new study. The two studies need not be identical as variables may be added or deleted from the definition. To maintain consistency, ClinAccess automatically checks to make sure that any variable which is added is defined in the Clinical Questions Catalog. The final step in defining a new table is to specify the primary key. The primary key is the variable or variables which uniquely identify each record in the table. This primary key is stored in a meta-data file and simplifies use of the data review components of the system.

Once the tables are defined, screens can be customized to resemble case report forms, and powerful cross field edit checks and computations can be performed during data entry. For example, to increase accuracy, clinical trial protocols often require blood pressure to be measured three times at each reading and the average used as the response. As shown in Figure 1, the data entry operator can enter the three sets of blood pressures and the mean will be accurately computed and stored in the dataset, available for immediate analysis.

Optionally, data can be entered a second time (double-key entry) to detect and prevent key stroke errors. Changes made to the data subsequently are captured in an audit trail.

Finally, the DBA can use the complete power of the SAS system's DATA and PROC steps to create data validation programs which can be customized for each study and run from a menu option.

Clinical Data Review Example

ClinAccess 2.5's strength continues to be the ease with which data can be accessed and manipulated. To illustrate this, let's take an example of how ClinAccess, can assist with reviewing laboratory data. The user will view the laboratory data, create a report displaying the data to take along on a site visit, generate a graph to detect a trend in a specific lab test over the course of the study, and then generate another report to examine the trend in detail.

Throughout this process, data integrity is constantly maintained. With the exception of the data entry options, no ClinAccess function changes data in the underlying database. All data manipulation, such as selecting subsets of patients, is performed on copies of the data and stored in the user's personal library.

To begin, the user selects the View option from the Main Menu. The user is given a choice of viewing data in Case Report Form or Table formats and decides to view the data in CRF format. The user then selects a study from a list of studies. For clarity, the list includes the study name or number and a brief description of the study (Figure 2). Thanks to ClinAccess's graphical user interface, the operation is completely point and shoot. The user merely positions the cursor on the study name by using a mouse or the tab key and clicks the mouse button or presses enter to make the selection. The user is presented with a list of data available to be viewed in the study and similarly makes a choice. The data is presented in a format resembling a Case Report Form so that it will be familiar to the reviewer (Figure 3). The reviewer can browse the data and perform queries.
Next the monitor would like a listing of the data, so that she can discuss the data with the investigator on the next site visit. She selects the Reports option on the Main Menu and chooses a Data Listing Report from the Reports menu. CunAccess remembers which study is being reviewed, so that there is no need to select the same study again. The user selects which variables will be included in the report in the order they are to appear from a list of variables which includes variable descriptions (Figure 4). Once again the variable selection process is point and shoot. The report is displayed on the screen and can be printed via a menu option (Figure 5).

Finally there is some concern that similar compounds have caused a decline in White Blood Cell counts. To detect a trend, the user selects the Graphics option and chooses a vertical bar chart. After selecting the variables to be graphed a chart is generated which appears to detect a decrease in WBC counts over time (Figure 6). To get more detail, the user selects the Descriptive Statistics report option from the Reports menu, selects the variable WBC for analysis, chooses statistics to compute from a list, and requests that the statistics be computed for each treatment group at each visit. The report indicates that there may indeed be some cause for concern about decreased white blood cell counts. The reviewer can then discuss performing some definitive tests with a biostatistician.
**Hematology Data**

**Study CUR002**

<table>
<thead>
<tr>
<th>Patient ID Number</th>
<th>Visit Number</th>
<th>Treatment</th>
<th>Sex</th>
<th>Hematocrit</th>
<th>Hemoglobin</th>
<th>White Blood Cells</th>
<th>Red Blood Cells</th>
<th>Platelets</th>
</tr>
</thead>
<tbody>
<tr>
<td>101</td>
<td>1</td>
<td>Curitol</td>
<td>Male</td>
<td>45</td>
<td>15.9</td>
<td>3.1</td>
<td>4.9</td>
<td>300</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Curitol</td>
<td>Male</td>
<td>54</td>
<td>15.4</td>
<td>6.5</td>
<td>5.6</td>
<td>190</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Curitol</td>
<td>Male</td>
<td>53</td>
<td>16.0</td>
<td>6.5</td>
<td>6.2</td>
<td>130</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Curitol</td>
<td>Male</td>
<td>45</td>
<td>16.0</td>
<td>5.5</td>
<td>5.2</td>
<td>330</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Curitol</td>
<td>Male</td>
<td>53</td>
<td>15.8</td>
<td>8.5</td>
<td>5.3</td>
<td>200</td>
</tr>
</tbody>
</table>

| 102              | 1            | Placebo   | Male| 46         | 17.7       | 9.4                | 5.4            | 350      |
|                  | 2            | Placebo   | Male| 47         | 17.0       | 7.5                | 4.7            | 250      |
|                  | 3            | Placebo   | Male| 56         | 17.2       | 8.1                | 5.4            | 260      |
|                  | 4            | Placebo   | Male| 45         | 16.8       | 8.0                | 5.1            | 180      |
|                  | 5            | Placebo   | Male| 59         | 15.5       | 9.0                | 5.2            | 260      |

| 103              | 1            | Curitol   | Male| 52         | 14.7       | 8.5                | 5.7            | 180      |
|                  | 2            | Curitol   | Male| 45         | 16.2       | 7.3                | 5.5            | 360      |
|                  | 3            | Curitol   | Male| 49         | 15.9       | 6.7                | 5.3            | 320      |
|                  | 4            | Curitol   | Male| 56         | 16.5       | 3.7                | 4.7            | 160      |
|                  | 5            | Curitol   | Male| 54         | 14.6       | 7.4                | 5.2            | 300      |

Source: ClinAccess™; MJR; February 18, 1992

**Figure 5: A Data Listing Report Produced by CUNACCESS**

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**FUTURE DIRECTIONS**

In 1990, SAS Institute introduced a new generation of the SAS System, Version 6.06. This release adds many capabilities, such as indexing and SQL, usually associated with relational databases. Additionally, the introduction of multiple engine architecture permits applications written with SAS software to directly access data stored in such popular databases as Oracle and IBM's DB2. Further details of these new capabilities are described in Rosenberg 1990.

Work is underway to exploit these new capabilities in future CUNACCESS releases. MAJARO is also exploring other computer platforms such as IBM mainframes, DEC Alpha computers, UNIX workstations, and Microsoft Windows.

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**SUMMARY**

The CANDA initiative begun in 1986 has advanced to the stage where the FDA has challenged the pharmaceutical industry to file all submissions with a CANDA component by 1995. In order for this to occur, the creation of CANDA's must be simplified and begun early in the clinical development process. The CUNACCESS clinical trials system is an important step in this direction. Developed entirely with SAS software, CUNACCESS is designed to provide monitors, CRA's, and other non-traditional users with access to the information stored in clinical databases. CUNACCESS provides: single or double-key data entry; viewing and querying of data; graphics; descriptive statistics; and report generation. Available on PC compatibles running SAS for OS/2, versions for Microsoft Windows, UNIX workstations, DEC Alpha AXP, and other
desktop platforms are under consideration or development.

For a number of years now, we've witnessed the evolution of SAS software into a product with greater interactivity and data management capabilities. Version 6 is a major step in that evolution. Companies that start now to exploit these new capabilities through systems such as CLINACCESS, have the potential of realizing substantial advantages over their competitors in terms of reducing the cost and time needed to bring a new drug to the market.

REFERENCES


ACKNOWLEDGMENTS

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