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CLIENT/SERVER/INTERNET COMPUTING AND STANDARDIZATION: THIS IS THE FUTURE DIRECTION FOR THE CLINICAL LABORATORY

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Summary: This paper describes how, since 1990s, we can use new technologies, object-oriented software tools and standardization for development in clinical laboratory. The paper will also explain how a laboratory could easily set up an automatic facility for general practioners to use Internet and browser tools to access results directly from the Laboratory Systems report files, and from there automatically capture the required patient information for integration. The files of clinical laboratory database (tests) are facing an increase in the number of test items, as well as a corresponding diversification due to the demands of medical institutions and the improvement in analytical techniques. To respond to this situation, medical institutions have been promoting systematization of their procedures. Information exchange among the institutions has likewise expanded with the use of media such as on-line systems, World Wide Web (WWW) and the Internet. This experience suggests that this approach will be the way forward for the high performance but user-friendly laboratory systems of the future.

Key words: server, internet, object-oriented software, World Wide Web, network, e-mail, LAN, WAN, HTML, URL, hypertext, Java, fuzzy logic

Introduction

Client/Server/Internet is at present one of the greatest sources of information, knowledge, reference materials, and educational and training programs for the general population, and especially for the professionals from clinical laboratories.

In the clinical laboratory, we have developed a strategy for optimizing the analysis of laboratory databases. The database analysis processes and compares all the laboratory data characterizing a web browser interface using standard Internet technology. The patient identification and serial comparison of the results of each patient are accurate and easy to perform. The database could be helpful in a specialized laboratory assay and could be connected with the hospital network.

Ironically, networking computing now predominantly supports human rather than computer communications. For the clinical laboratory, the internet provides high-speed communications through e-mail and allows the retrieval of important information held in repositories. All this capability comes at a price, including the need to manage a complex technology and the risk of intrusions on patient privacy.

One of the major trends in computing for the 1990s is the move towards distributed systems based on Client/Server/Internet architecture. Although a recent survey has suggested the need of planning to adopt this new technology, there is little evidence at present of similar progress in the field of clinical laboratory computing (1). Standardization of interfaces has been proposed to secure a common framework compatible with different types of information. Network databases allow users to retrieve data in multiple ways and resolve the problems associated with having multiple copies of the same data by setting up multiple access pointers to a single data element. With the aim of achieving best practice in Laboratory Automation System (LAS) or Laboratory Information System (LIS), they present the results of a questionnaire survey of LAS or LIS (2, 3).

LISs have evolved into complex applications to meet the specialized needs of laboratories. As integrated delivery systems (IDSs) continue to emerge as

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the dominant model for healthcare delivery, clinical laboratories serving them face two imperatives that affect IDS decisions. First, laboratories in IDSs must consolidate to reduce costs and duplication, yet deliver services across a region in both in-patient and out-patient settings. Second, laboratories that successfully perform reference laboratory testing will increase revenue, generate referrals, and leverage excess capacity.

Computer networks: What is World Wide Web? How will we use it in Laboratory Information Systems?

A computer network, or network, is a concept separate from the network database model. A network is any interconnection between computer systems or between a computer terminal and a computer laboratory system that supports the interchange of data. If the network is physically located within a limited locale, such as 1 to 2 miles, it is called a local area network, or LAN. If the network spans a larger area, it is called a wide-area network, or WAN. High-speed LAN technology is inexpensive and often user-installed. Most computers include Ethernet as an integral part of the hardware, and such systems require networks to communicate with other computers, such as the network for Adapter Data Transfer (ADT) and billing functions. Interchanging data between different computers requires software to support a common protocol, or an agreed-upon way to interchange data. Unfortunately, incompatibilities between software vendors, hardware vendors, and applications software often make this interchange highly complex (4). The Web is not identical to the Internet. It is one of many Internet-based communication systems. World Wide Web (WWW) and the Internet function are using the analogy with the global road system. The basic idea of WWW is to merge the techniques of computer networking and hypertext into a powerful and easy to use global information system. Hypertext is text with links to further information, based on the model of references in scientific papers (5). Hypertext Markup Language (HTML) or hypertext is a way to organize documents so that your computer can help you find items of interest.

As networks advance in speed and capability, computer systems implementing a Client/Server architecture have emerged. This term describes a specific interaction between two networked computers. The server computer holds the database from which clients retrieve and process data for their use. If a clients updates the data, that will automatically update the data on the server. Uniform Resource Language (URL) address is the name of the address. It includes the information on where the file is located and what a user can do with the browser. Every file in the Internet has a unique URL. The client/server approach has become popular with LIS systems in

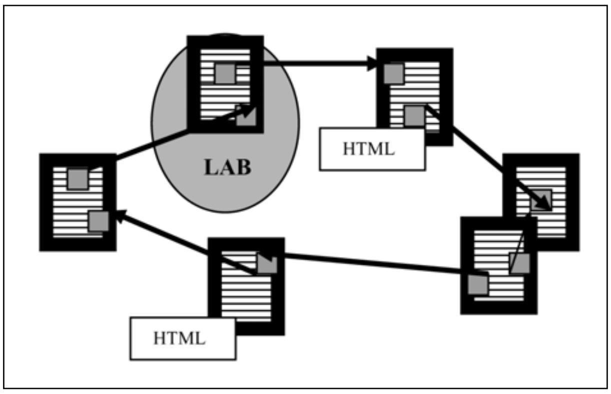

Figure 1 Hypertext as a way to organize documents

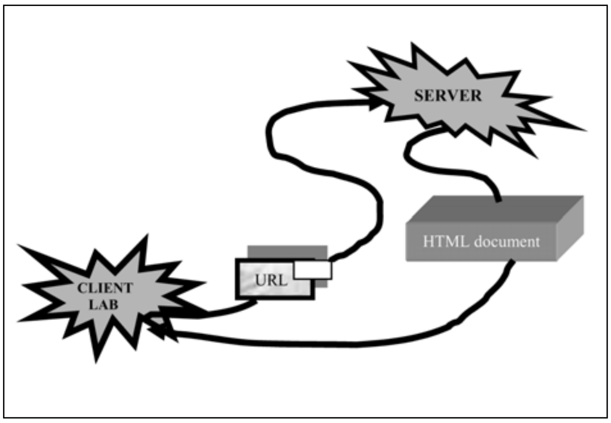

Figure 2 Client/Server architecture

two areas. With smaller systems, some vendors have implemented LISs with inexpensive personal computers and Client/Server software, replacing more expensive minicomputer-based systems. Larger systems have implemented a server architecture to allow users with personal computers to download data so that they can process it independently (1).

The other group of tasks which are used is Embedded Systems are computers or microchip-based control systems that are dedicated to performing specific tasks. Embedded systems have been applied to a variety of medicine tools and laboratory tools. Embedded systems are cheaper and more reliable than today's software used in PCs. With the advance in the Internet technology, a lot of electronic goods – laser printers, computers, security monitors, medical tools will be connected by a global network called the Embedded Internet. The Embedded Internet will perform many tasks, as the automated control/monitoring on production lines. This connection can be further extended to include LAN, WAN, CAN (Control Area Network) and CEBus (Commercial Electronic Bus). CAN is a European protocol that provides a standard method for real time. When Java applets are

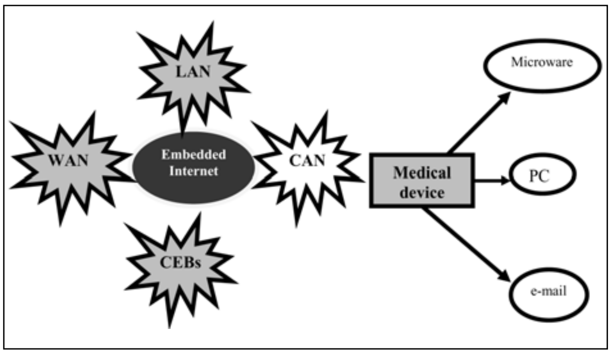

Figure 3 The connection of Embedded systems with LAB

loaded into the MCUs (microprocessor), CPUs (Central Processor Unit), and other microchips embedded in the target systems connected to the Internet via LAN, WAN, CEBus, or CAN topologies, they make the Embedded Internet.

Microwave, satellite, and other frequency systems are supporting mobile information-gathering activities. For example, some vendors are providing hand-held portable units for phlebotomists to increase the accuracy of collection times, and for better patient identification. Advanced paging devices linked to the LIS allow physicians to have immediate access to patient data as soon as it has been verified. These systems may also be used to interconnect computer systems where cables cannot be used or are inconvenient. Most of these mobile technologies are substantially more expensive than cable-based systems. The effect of all these network technologies has been to allow the integration of information from physically diverse locations. In many institutions, networks are critical in supporting satellite laboratory facilities, allowing the satellites to have access to patient data, and in many cases allowing the creation of structures that support a decentralized physical and organizational operation. Such satellite operations are becoming increasingly important as laboratories grow to meet expanding health care alliances (6).

Development of Embedded Internet using Java has emerged as the most widely adopted programming language for the Internet applications. There are four advantages over other methods for using Java applets for distributed control over the Internet: 1) web browsers are readily available and offer a highly programmable and configurable user interface; 2) Java code size is up to 50% less than machine instructions, making it highly attractive to MCU-based controls where RAM memory size is limited; 3) most of the hardware and software is readily available, and no extra investment or development is needed; and 4) there is no need for developers to reinvent software since most MCUs' kernels or PCs operating systems will support Java and TCPI/IP (network protocol) which helps the computers in the Internet talk to each other and HTTP.

The electronic mail (e-mail) was popular with the computers networked, and scientists used it to facilitate their communications. Different computers often used different communication protocols, and this prevented exchange of information. TCP/IP (transmission control protocol-internetwork protocol) was developed to overcome this, and it gradually became the dominant protocol. The name Internet originates from IP, the abbreviation for »internetwork protocol« (6).

A simplified Embedded Internet consists of web browsers at one or more sites, target embedded systems (such as of laboratory tools) at same or different geographic locations, and the MCUs embedded in these target systems. The MCUs are the devices that store Java applets to execute the controlling or monitoring functions on the controlled targets, using either classical method (feedback) or fuzzy logic method (7) (see *Figure 4*).

In such a networked system, transferring HTML pages and executing Java applets achieve distributed control. A user at one central site can use a web browser to access HTML pages from one or more target embedded systems, along with Java objects that have been inserted into them, and execute Java objects to perform the control operations programmed. After executing one or more such Java objects from a web browser, the user can then send tasks to the targets, which are represented in HTML pages plus same Java objects, to perform remote or distributed control of the targets (LAB tools). To create new tasks or to update old tasks at a target, the user at the central site can send via FTP (F Transfer Protocol) software objects (Java applets) to the target site where they are to be stored inside the MCU and executed when needed (7).

A database in LIS with a network data relationship

This data model very efficiently utilizes computer resources and can be very effective in many situations. Unfortunately, the relationships between various data elements can become very complex and difficult to understand. Such complexities could become particularly problematic should data relationships change; that is, systems built using network model database managers are easily created but difficult to maintain. Most common database managers are based on the network model (8).

The *relational database management system* has become popular because of its easy use. The data appear as tables, and database operations become operations on tables that users can perform with ease (9). This flexibility has earned relational databases a large role in situations where data are manipulated frequently, as in a research setting. A side effect of this flexibility is that relational databases

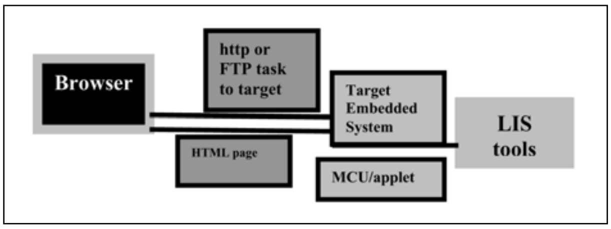

Figure 4 A database with a network data relationship. The data are organized so that they can be retrieved either by the patient or by abnormal results.

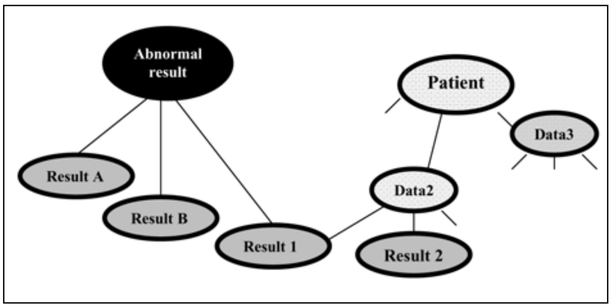

Figure 5 A database with a network data relationship. The data are organized so that they can be retrieved either by the patient or by abnormal results.

utilize computer resources less efficiently than simpler models do, and this may present problems with very large datasets. Some examples of relational databases are IBM's DB2, Oracle, and Sybase. Many other databases often claim to be relational, but are based on the network model. Few LISs use relational databases for high-volume data transactions because of performance and cost issues, though some systems transfer data from a no-relational production database manager to a relational database manager for *ad hoc* queries. These hybrid approaches may completely move to a relational database manager as hardware resources become cheaper (10).

Data structures are critical to the design of programs. First, stored patient data in an LIS consume most of the disk and memory storage. In an LIS, the amount of laboratory data easily exceeds the programs needed to run a system by several orders of magnitude. The design of the data structure may impose limitations on stored information. One system might be limited to storing data on 2,000 patients, whereas a second system might be limited to 64,000 patients. The vendor of the smaller system may have made this restriction so that their LIS runs faster and more efficiently and requires less disk storage, thus producing a system less expensive than the larger one. But this efficiency is irrelevant if the user's needs exceed 2,000 active patient files (10).

Integrating and presenting clinical outcome data

Clinical information system integrates various sources of clinical data and facilities outcome assessment for patients evaluated in a lumbar spine service. During an encounter with a patient, the physician formulates a hypothesis regarding appropriate forms of treatment, and he or she may then use this system to explore previous treatment outcomes for similar cases. The availability of a clinical tool that presents information in an outcome-oriented format may be highly relevant for the delivery of cost-efficient, high-quality health care and also create a formal mechanism for detecting practice variability.

Automated laboratory protocols

A protocol is a program which controls, monitors and modifies the requests for laboratory services during the diagnostic work-up and/or monitoring of a patient. A protocol language and an OS/2 based system for the compilation, interpretation and execution of laboratory protocols written in this language are presented. The system is easily interfaced with any patient database that supports the structured query language (SQL). A compiled protocol may be assigned to a patient and executed as specified in the protocol itself (regularly and/or when certain events such as test requests or arrival of results occur). In the laboratory protocol language, a patient's data are viewed as a set of test procedure groups, each comprising data (request time, result, etc.) describing the status of one or more simultaneously made laboratory test requests. A pattern specification is a statement saying that a sequence of test procedure groups of specified types and ages is present in the data. Pattern specifications are linked to Boolean variables. If a pattern matching a pattern specification is found in the patient's database, the corresponding Boolean variable is set equal to TRUE. The Boolean variables are utilized in the decision logic of the protocol (2).

Standardization

Some embodiments include: (1) Interface Standards on Clinical Laboratory Information. For information exchange, the format and reporting comments used in the media systems were standardized under the sponsorship of the Medical Information System Development Center, with a publication issued in 1993; (2) Standardization of Laboratory Test Code Standards development and data interchange.

To address the high cost of software development and the lack of coordination between the various information systems, the health care computer industry, LIS and Hospital Information System (HIS) users, and the federal government have created voluntary groups to set standards, particularly for the interconnection between information systems and

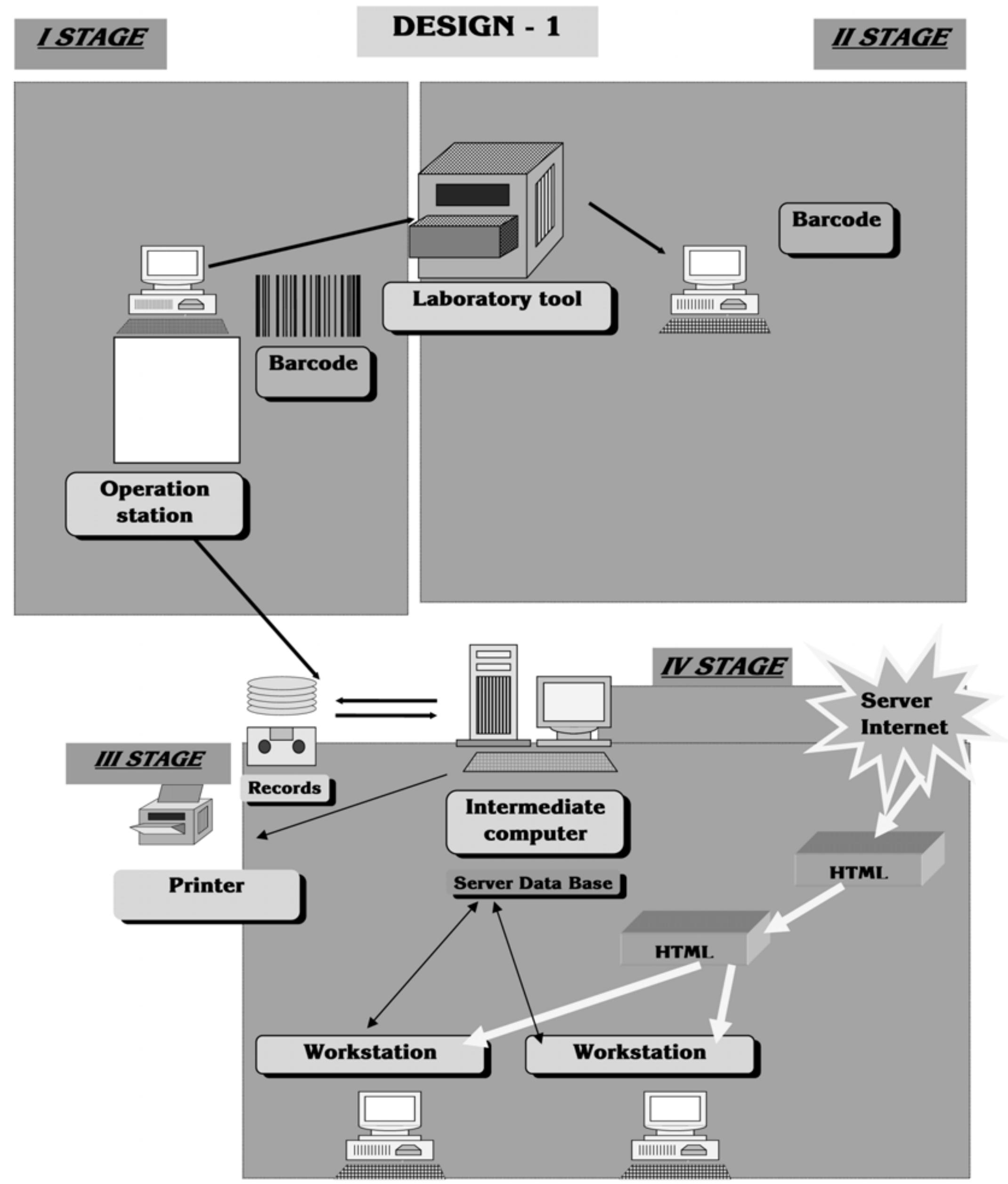

Figure 6 Laboratory integrated system

between an information system and computerized equipment. For the clinical laboratory, standards address the interchange of data (1) with bedside monitoring systems, (2) with administrative systems, including those associated with payers and government agencies, and (3) between laboratory systems. Of particular importance are those functions covering the interchange of laboratory test requests and results. Three voluntary groups that have created standards in the laboratory arena include the American Society for Testing and Materials (ASTM), already mentioned earlier with regard to automated instrumentation, the Institute of Electrical and Electronics Engineers, and the HL7 committee (3, 11). The HL7 committee was specifically formed to develop standards for supporting the interchange of information between computers in the hospital environment. Areas covered by the HL7 committee have included ADT, billing, patient demographics, orders, and results. The ASTM El 238 protocol has become the basis for systems interchanging laboratory data between different systems. Many reference laboratory

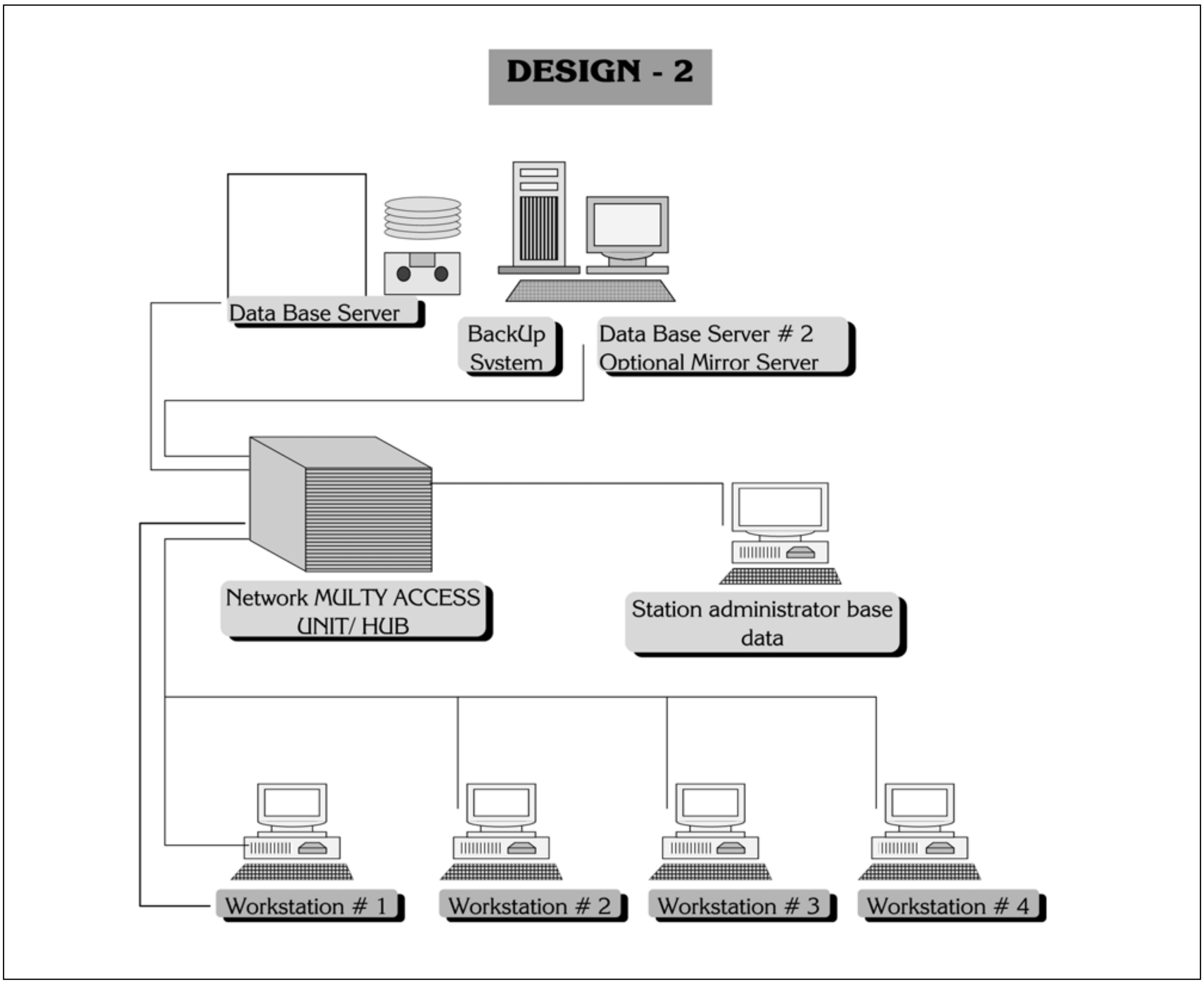

Figure 7 Design of Laboratory Information System

systems exchange data with hospital laboratory systems using this standard. Interfaces between an HIS and an LIS often use the El 238 standard or a similar subset as defined by HL7. These hospital standards for information interchange carry profound implications for LISs, for they offer large system-wide benefits at low additional LIS cost. For example, significant savings result from physicians directly performing order entry and retrieving results electronically, a task that requires integration of the HIS and the LIS. The ultimate goal of integrating interfaces is the migration toward a reduction in paper use and toward the electronic patient chart. This will be difficult until medical terminology becomes more consistent (5).

Software standards simplify communication and cooperation between applications provided by different software vendors. However, adherence to a rigid standard can stifle innovation. Open standards, which are not proprietary to any particular vendor, are particularly useful. Many standard-setting organizations have provided useful tools for laboratory informatics, including ASTM, Institute of Electrical and Electronics Engineers, National Committee for Clinical Laboratory Standards, and the College of American Pathologists. Data communication standards, such as ASTM 1238, HL7, and Digital Image Communication of Medicine, have reduced the cost and improved the timeliness of interfaces. Nomenclatures, particularly the Systematized Nomenclature of Medicine (SNOMED), have facilitated the structuring of medical information, and decision rules can be communicated with ASTM E1460. Laboratory Observation Identifier Names and Codes has eased the problem of identifying tests during interchange of laboratory data. Implementation standards are useful references for those deploying information systems. Standards have provided multiple benefits to laboratories and to the health care organizations of which they are components.

Recent advances in tools for scientific data acquisition, visualization, and analysis have lead to growing information management problems for medical research laboratories. An exponential increase in the volume of data, combined with a proliferation of heterogeneous formats and autonomous systems, has driven the need for flexible and powerful Experiment Management Systems (EMS). This paper provides a detailed analysis of the informatics requirements of an EMS, and proposes a new type of middleware called an EMS-Building Environment (EMSBE), which enables the rapid development of web-based systems for managing laboratory data and workflow. We describe the Web-Interfacing Repository Manager (WIRM), an open-source application server for building customizable experiment management systems. WIRM is being used to manage several ongoing experiments, including a natural language (12–16).

Conclusion

In the new technologies, information will be a value as well as a commodity. In the case of global commerce, this web information may be about corporate development. The aim is to develop a distributed hypermedia system over high-speed network. The hypermedia system supports: high-level nodes; dynamic links; sessions; multiple concurrent users; intelligent information customization; search and browsing over large hyperbases; and automatic hypertext engineering. The targeted applications for the system include computer-aided learning and distributed information system.

Possibly the greatest potential for changing the human–computer interaction comes from new computer technology being introduced today. These technologies have the advantage of being potently easier to use than the keyboard, but reliability of these devices must increase before they are acceptable for use in most areas of the clinical laboratory.

The use of computers in the clinical laboratory is still in the development stage. The potential of LIS systems to help manage the automation flow required for good patient care and to help effectively manage the resources required (costs) has barely been used. We can imagine a future where informatics will be as important as the analytical result.

Major problems associated with the Internet include exposure of computer systems to malicious attacks, possible loss of privacy in computerized patient information, complexity in supporting networks and networked computers, and the inaccuracy of some information being distributed. Any computer on the Internet is potentially vulnerable to data destruction. Break-ins by malicious users are probably the biggest problem. Data destruction by viruses and worms acquired through the network is a lower risk event.

As the use of the Internet spreads and users become more heterogeneous, its distinction as an elite resource will likely disappear. Moreover, the Internet can provide so much information that users are overloaded. Despite these negative, characteristics, the Internet remains a valuable resource for communication and for information, and permits the laboratory user to work in a manner more consistent with today's needs.

KLIJENT/SERVER/INTERNET KOMPJUTERIZACIJA I STANDARDIZACIJA: TO JE BUDUĆA SMERNICA ZA KLINIČKU LABORATORIJU

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Kratak sadržaj: Ovaj rad opisuje kako od 1990-tih možemo koristiti nove tehnologije, objektno-orijentisanu (neproceduralnu) softversku opremu i standardizaciju, za razvoj u kliničkoj laboratoriji. U ovom radu takođe je objašnjeno kako bi laboratorija mogla jednostavno postaviti automatsku olakšicu za opštu upotrebu radi korišćenja pristupa internetu i sredstvima za pregledavanje, za pristup rezultatima direktno iz fajlova laboratorijskog sistema, i da odatle, radi integracije, automatski pokupi sve potrebne informacije o pacijentu. Fajlovi baza podataka (testovi) kliničkih laboratorija se suočavaju sa porastom u broju detalja za testove, kao i sa odgovarajućim raznolikostima usled zahteva medicinskih ustanova i unapređivanja analitičkih tehnika. Kao odgovor na ovu situaciju, medicinske ustanove unapređuju sistematizaciju svojih procedura. Razmena informacija između ustanova se takođe odvija uz pomoć medija kao sto su on-line sistemi, World Wide Web (WWW) i internet. Ovo iskustvo preporučuje da će ovakav pristup biti put ka unapređenju visoko performatnih ali i predusetljivih laboratorijskih sistema budućnosti.

Ključne reči: server, internet, objektno-orijentisani softver, World Wide Web, mreža, e-mail, LAN, WAN, HTML, URL, hipertekst, Java, nejasna logika

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