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Review Paper

Multimedia Workstations: Electronic Assistants for Health-Care Professionals

Abstract: The increasing costs of health care and the economic reality has produced an interesting paradox for the health professional to perform more clinical work with fewer support personnel. Moreover, an explosion of the knowledge-base that underlies sound clinical care not only makes effective time management critical, but also knowledge management compelling. A multimedia workstation is an electronic assistant for the busy health professional that can help with administrative tasks and give access to clinical information and knowledge networks. The multimedia nature of processed information reflects an evolution of medical technologies that involve more and more complex objects such as video sequences or digitized signals. Analysis of the 445 Medline-indexed publications for the January 1991 to December 1994 period, that included the word "workstation" either in their title or in their abstract, helps in refining objectives and challenges both for health professionals and decision makers. From an engineering perspective, development of a workstation requires the integration into the same environments of tools to localize, access, manipulate and communicate the required information. The long-term goal is to establish an easy access in a collaborative working environment that gives the end-user the feeling of a single virtual health enterprise, driven by an integrated computer system when the information system relies on a set of heterogeneous and geographically distributed components. Consequences in terms of migration from traditional client/server architectures to more client/network architectures are considered.

Keywords: Health-care Professional Workstation, Software Engineering, Integration, Internet, Intranet

1. Introduction

Health-care professionals depend on accurate and timely access to information about the patients under their care, information contained in the biomedical literature, and information accumulating in databases around the world. However, the promise of the information age has not been realized in health-care because of the technical short-sightedness of closed systems and sociopolitical boundaries that inhibit collaboration and data sharing. Because of continued purchasing of closed-end solutions, health-care facilities are still not in a position to provide their professionals with transparent access to distributed patient data, knowledge sources, and processing services. The workstation for the health-care professional provides both a short-term solution to the problem of inadequate information infrastructures and an evolutionary path toward an integrated information environment [1-3]. The development of such a workstation involves consideration from the viewpoints of the end-user, the engineer, and the health administrator.

From the end-user's perspective (physician, nurse, etc.), the workstation can be more than a data and knowledge integrator. Through evolutionary steps, the workstation will first serve the information needs for patient care, support professional and personal communications, provide decision support, and facilitate professional and personal task management [4-8]. The workstation needs to evolve from an information display device into a work-facilitating device with the goal of becoming an intelligent electronic assistant.

From the engineer's perspective, the workstation is the unique mediator between the health-care professional and the health network that conceals the complexity of the underlying information system. It is a hardware and software framework that needs to address interface management, secure communication, processing and control, and eventually local storage. Physically, these processes can be combined within the same box or distributed over a network.Their development should benefit from a careful evaluation of end-user needs and appropriate software-engineering techniques [2,9,10].

Finally, from the health administrator's perspective, the workstation is a new technology that needs to be integrated into the organization and have proved cost/effectiveness [11]. This technology, however, is nothing less than a radical structural agent of change. The device can enhance productivity, change communication patterns and, hence, the ways in which professionals and support staff collaborate in the care process, provide the technical ingredients for true continuous quality improvement, and facilitate the collection of the data necessary for executive decision support.

2. Functional Requirements

2.1. The Expression of End-users' Needs

It is traditional in health care to assume that the functions of a computerized system should be patient-centered and the developments user-entered. Interfaces and accessible functions need to be tailored to the expressed needs of individual users or categories of users (e.g., general practitioners, radiologists, nurses). Indeed, the participation of end-users in the development process and in evaluation teams with designers and external evaluators minimizes the risk of inappropriate design and provides the necessary feedback on the viability of the first prototypes [12-15].

But end-users' reactions are often conflicting and biased by their personal experiences with products of previous generations. Comments on a prototype are different from experiments in a real situation. Such experiments require mature and secure products, and it becomes more difficult at this stage to make drastic changes. Economic pressures impose the need for a large market to balance the high cost of development. End-users' expectations are likely to be tempered by the constraint of minimal consensual functions and the need, at the institution level, to facilitate transitions.

2.2. Organizational and Technological Trends

Requirements must also be based on the prospective understanding of the changes in the delivery of care and in the technology. Table 1 illustrates, through the analysis of Medline indexed publications from January 1st, 1991 to December 31st, 1994, the growing interest for workstations. A total of 445 publications included the term "workstation", either in their title or in their abstract. The number of

Period	**1991-1992**	**1993-1994**	**Total (100%)**
Nature of the publication	(%)	(%)	(%)
Analysis and design, review papers	15,6	23,7	20,2
Development, derscriptive papers	65,1	57,7	60,9
Evaluation papers	19,3	18,6	18,9
Total no (1)	***192***	***253***	***445***
Main application domain covered			
Generic	10,4	5,5	7,6
Health-care units	18,8	31,6	26,1
Radiology, PACS, radiotherapy	35,9	31,6	33,5
Biology, genetics, molecular biology	8,9	12,6	11,0
Anatomopathology	8,9	5,1	6,7
Surgical processing	3,1	4,0	3,6
Signal processing	3,1	2,4	2,7
Education	4,2	1,6	2,7
Access to data and knowledge banks	4,7	0,8	2,5
Epidemiology, clinical research	0,5	3,6	2,2
Workstations for disabled people	1,6	1,2	1,3
Total no (1)	***192***	***253***	***445***
Total number of publications in Medline (2)	**752,528**	**759,666**	**1,512,194**
Ratio (1)/(2)	0,026%	0,033%	0,029%

Table 1.
Nature and domain of publications covered by the 445 publications from 1991 to 1994, indexed in Medline and including in their title or their summary the term "workstation".

publications has increased by 32% from the period 1991-1992 to the period 1993-1994. Application domains cover all medical fields and mainly health-care units, radiology, biology and pathology. The number of true evaluation papers is low by comparison with design papers, descriptive papers and literature reviews.

However, the recent development of community health-information networks (CHIN) and the current explosion of Internet- and Intranet-based experiences will significantly change for the years to come the vision of the functionalities and architecture of a workstation [16,17].

2.3. A Typology of Functionalities

Table 2, derived from the literature and the personal experience of the authors, summarizes some key functional requirements of an intelligent workstation for the health professional [1,4-9]. Group 1 and part of group 5 functions are clearly patient centered. Group 3 and 4 indicate that direct help to the end users' activity is a necessary condition of acceptability and success. Group 2 to 4 functions concern both the end-users and their environment (e.g., the institution).

Development of CHINs raises the issue of the ubiquitous, rapid and secure management of permanent patient records. A workstation is the key tool on which the integration of the distributed pieces of the patient record (from various servers) can be achieved. Communication between professionals (within or between institutions) and cooperative work (groupware) become essential [18-20]. Simultaneous consultation of the patient record and distance interaction constitute the foundation of such cooperative work.

Requirements in terms of multimedia object management are highly dependent on the context; for example, the display and simple manipulation of selected images at the physician's office or in the hospital ward, and the interpretation and selection of important images by the production sites, such as radiology or pathology departments [21]. In the latter case, both the speed of access to sequences of images and the quality of the displays are crucial acceptability factors [22,23].

Table 2. Selected functional requirements.

1. **Ability to help the medical practice (direct patient care support)**
   Computerized patient record update and consultation
   - data recording (administrative, medical, nursing, investigations)
   - multimedia object management (e.g., text, graphics, images, sounds)
   - data presentation (e.g., summaries, flow sheets, graphics)
   - simultaneous record consultation (group work, staff discussions)

   Decision support
   - clinical calculations (e.g., drug doses, predictive value of a sign or symptom)
   - search for similar patient cases
   - access to contextual knowledge (intelligent agents)
   - diagnostic and therapeutic suggestions
   - prognosis evaluation
   - strategy selection support
   - follow-up support (e.g., monitoring and alerts, follow-up reminders, compliance evaluation)
2. **Support to the management of the health care professional environment**
   - health-care unit management (resources, planning)
   - access to reference information (e.g., protocols, consensus reports)
   - evaluation of medical procedures (e.g., outcome measures)
3. **Teaching and research**
   - access to literature
   - access to external data and knowledge banks (e.g., drugs, clinical trials)
   - end user assistance (e.g., on-line help, tutorials)
   - support to continuous education
4. **Logistic capabilities**
   - desktop publishing (e.g., text processing, spreadsheets, presentation tools)
   - communication facilities (e.g., mailing, file/record transmission, Internet and Intranet tools)
   - personal data management (e.g., agenda, addresses)
   - personalization, customization of the workstation
5. **Protection, security and confidentiality**
   - end-user identification and authentication (e.g., professional smart cards)
   - data integrity and security management
   - maintenance of patient data privacy and confidentiality

Decision support can be passive, at the end-user's request, or active driven by the health-care context (e.g., alarms, reminders, automatic diagnosis or therapeutic suggestions). In the context of widely available networks, several decision-support strategies have to be balanced within the limited time frame that a physician can devote to a patient's case:
- find similar cases to evaluate what has been done and achieved [24-26],
- ask advice from colleagues through telemedicine consultation [18-20],
- find relevant literature and knowledge [17,27-29].

3. Development Tools and Strategies

3.1. Analysis and Design Tools

Design and implementation of an intelligent workstation are growing processes in which new functions are gradually added to existing ones. Changeability and adaptability are essential. For the workstation developer, the long-term objective is to conceive a virtual environment that gives the end-user the illusion of a single and unique application, despite the fact that the functions rely on a set of distributed and heterogeneous pieces of hardware and software. Development is facilitated if the workstation software is initially conceived in a modular client/server design in which each component conforms to a normalized interface protocol [9,10,30]. The Domain-Specific Software Architecture (DSSA) methodology is an example of producing specifications that permit the assembly of specialized components for a particular domain [31].

The main goal of an analysis and design tool is clearly to increase both productivity and quality in workstation developments. One way to reach this goal is to provide analysis and design tools supporting re-use. Reusability, which can be fostered by encapsulation and information hiding, together with the need of a uniform method able to cover all the modeling aspects quoted before, highlights the interest of using object-oriented analysis and design methods [32]. These methods ensure that the same ideas and concepts are manipulated from the requirements phase down to the implementation phase (i.e., there is no paradigm shift between the different stages of the life cycle), that the system dynamics (i.e., how the objects interact with one another) can be easily handled, and that the potential decentralized architecture is carefully taken into account (i.e., through message sending interaction modelling) [33,34]. In addition, spiral models of development enhance changeability and adaptability. For these reasons, the analysis and design tool of a workstation development environment should benefit from being based on such methods.

3.2. *Medical Object Modeling and Management*

Medical information must be transparently accessible whatever its nature or location. Thus, objects to be handled by a workstation include local (on the workstation) or foreign objects (within the institution, such as those found in hospital information system databases, or outside the institution, such as those accessible through the Internet). Those objects may be simple or complex objects (e.g., multimedia), static or dynamic (e.g., actions and procedures, such as protocols or decision-making processes).

If the communication aspects (i.e., how to reach and to interact with the desired objects) have to be handled at run time, development time is deeply concerned with object modeling. At that time, two complementary aspects must be considered: how the workstation functions and processes will be able to interact uniformly with heterogeneous objects, and how the necessary semantic integration between objects originating from various places will be achieved at the workstation. The first point can take advantage of the emergence of standards such as OMG's CORBA. Thanks to its normalized object-interface description (through the use of the Interface Description Language, IDL), the availability of compatible Interface Repositories implemented by most of the Object Request Brokers (ORB), the CORBA approach allows objects of different origins to interact with one another and thus improve software modularity [35]. The repository stores the location of the foreign objects as well as the operations available for a given object and the means to access them. Indeed, as long as an object can issue a request in a standard format, called for by a standardized object-request broker, objects can communicate transparently across different languages and platforms. Using such an approach, workstation development environments can deal both with components specifically designed and implemented for use in a medical workstation, and with the encapsulation of external components that were not initially designed to cooperate (e.g., a text editor, a spreadsheet, a decision-support system) [36].

With the globalization of health networks, sources for relevant medical objects will be more and more located outside the hospital. Management of foreign objects will thus become a key issue that will involve both data management and communication tools. Object-oriented techniques can facilitate the constitution of metamodels of accessible data structures [9,30,37,38]. In that respect, the design and implementation of a "foreign objects cache" together with the necessary "intelligent agents" to feed the cache asynchronously with the workstation use of the retrieved objects have to be considered [39]. Besides performing the necessary translation between different types of information presentation (e.g., different medical data-encoding schemes), the communication tools, together with the data management tools, have to guarantee the semantic mapping between objects that may have been modeled differently [40,41].

3.3. *Interface Management*

Graphic user-interface management systems must allow medical application developers to create end-user interfaces that are adapted to their professional habits and comply with medical style guides [42]. Indeed, end-users must be able to move between components that share a common look and feel, in order to minimize the component-training period and enhance acceptance of the workstation. Ethnographic studies of end-users' work practices (e.g., through video recording) might provide a better understanding of the cognitive processes involved in human-machine interaction, the barriers encountered, and the effect of education and training [14,43]. Health professionals are frequently interrupted in their activities. It is thus very important to be able to interrupt a transaction, to record the state of the interface when the interruption occurred, and then to be able to resume the stored configuration.

From a technical point of view, the interface manager must comprise all the basic building blocks necessary to give life to multimedia objects (e.g., texts, charts, images) and to benefit from audio and video extensions (voice commanding, input or production of audio documents, synchronizing audio with video). It is commonly stated that developing a convenient user interface for a software product can currently represent more than half of the programming-efforts. User Interface Management Systems (UIMS) have then evolved from programming intensive systems limited to part of the software life cycle, to highly interactive tools that can be used throughout all the phases of this cycle [44]. Rapid prototyping capabilities become particularly important. Traditional UIMS give priority to multi-windowing, direct object manipulation, complex graphical and multimedia management facilities and re-usability of interface components. Generally, these products offer convenient features to rapidly build "static" interfaces, but prototyping the dynamic behavior (i.e., the link between the interface and the application) remains difficult to handle correctly (even through the use of callback editors), because most tools impose to bind application control at compilation time.

Internet-based applications open new opportunities for building integrated interfaces [16,26,45,46]. The increasing use of Web browsers as unique client interfaces to access all Internet and Intranet information servers (through additional built-in functionalities such as E-mail or news handling, helper applications located at the workstation side, dedicated plug-ins, or the ability to load applets from the network) could provide a valuable example of what should be the user interface of tomorrow's medical workstation. From the development standpoint, such an approach will lead to lighter (since most of the Input/Output will be borrowed from the browser) and more portable code (through the use of the Java™ abstract windowing toolkit for instance). Moreover, when in the past respect of style guides was left to the programmer's opinion, the use of a unique interaction metaphor (i.e., through a browser) enhanced by the use of a common implementation language and framework will favor the appearance of medical applications really sharing a common look and feel.

In a prospective view, the availability of development tools to build Internet sites, able to deal with 3-D applications and virtual reality (through the use of the VRML language), could open the way to a new evolution in man-machine interaction and to the appearance of a new interaction metaphor more adapted for clinical use than the traditional 2-D desktop metaphor.

4. Components of the Multimedia Workstation

4.1. Hardware Environment

Physically, components of the workstation can be gathered within the same box (i.e., machine) or distributed among several machines linked by a network (e.g., combination of graphic terminal, data and information-processing servers). The need for ubiquitous access to information allows for different categories of workstations (i.e., sedentary or nomadic).

A sedentary workstation generally amounts to a multimedia computer (PC or Macintosh, UNIX workstation, or adapted X terminal). This standard hardware that always includes a high-resolution color display (to visualize still and live pictures) and a network connection (generally Ethernet based) can be enhanced with various input/output devices depending on the specific needs (e.g., microphone and digital video camera, speakers, fast modems or ISDN connections, ATM switches). A smart-card reader could be a convenient way to ensure identifications of users (both health-care professionals and their patients) if they want to access sensitive information. This kind of sedentary workstation is generally seen in hospital wards, staff meeting rooms, and medical personal offices.

Nomadic workstations, through their data-input modes (stylus on a sensitive screen, coupled with an efficient manual writing OCR) mimics an electronic writing pad and is generally implemented in a palmtop such as the Apple Newton. It allows the input and consultation of basic information to be connected to the network through wireless (radio or infrared) connections.

But with the rapid spread of Internet and Intranet technologies, health-care enterprises seem ready to change their "computer model". The ever and ever-more powerful workstations (generally PC based) could decline due to their inherent costs and difficulties to be managed and updated for the benefit of "network-like computers" (NC). In the latter approach, all the power is transferred to the network and the connected servers, and the NC amounts to an Internet browser, probably a PC without storage, which is externally maintained via the Net.

4.2. Software Components

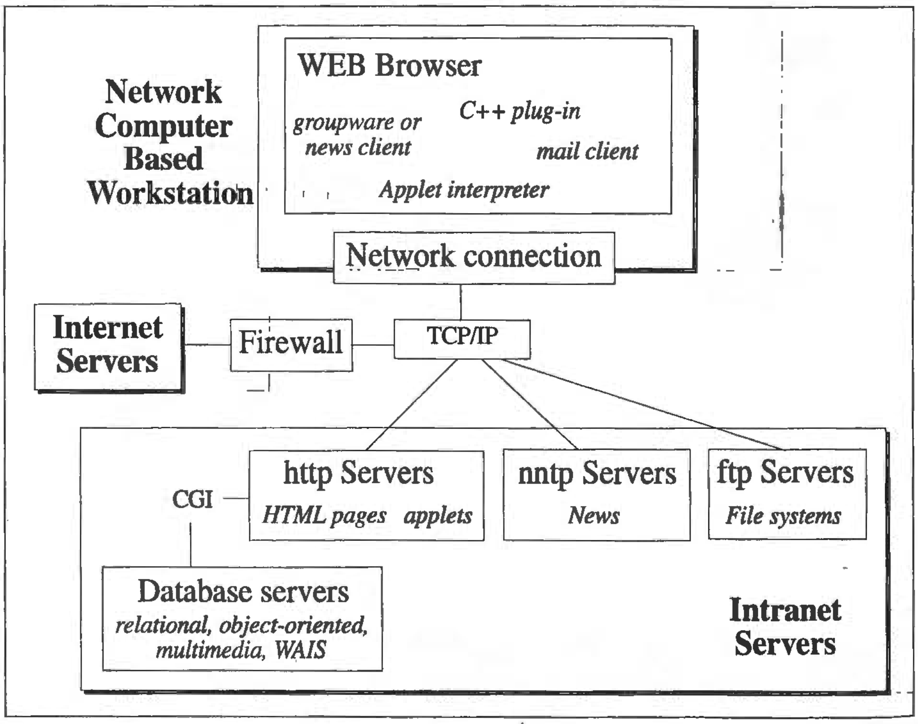
From the study of health-care professionals' needs, it is possible to define the functional architecture and the software components needed for its implementation.

In a "traditional" client/server approach (i.e., the workstation is in turn a client for different dedicated servers), five software components could be considered as generic, and should be integrated: an interface manager, a local data and knowledge manager, a communication manager, a security manager and a control (or supervisor) component [9,51]. Of course, the precise interrelationships of these components will depend on the chosen hardware infrastructure.

1. The interface manager, considered as a mediator between the user and the workstation, must allow for easy interaction with any modality of medical information, either mono- or multimedia. In addition, this component must be in phase with the work environment. In particular, it must ease the sharing of a workstation between several users, while guaranteeing confidentiality of the accessed data and memorization of user preferences.
2. The data manager should allow for storage and local management of user data, while facilitating access to local and remote servers for downloading relevant data (e.g., parts of a medical record or knowledge elements such as a protocol).
3. Communication functions must enforce access to relevant information, whatever its nature or location, and ease groupware (e.g., access to remote data, tele-expertise, simultaneous consultation from various locations of the same record). Workstation communication tools must then be designed to integrate current and upcoming message-handling standards [47-48].
4. Security management is of particular concern with objects scattered in wide-area networks [49,50]. The functions should address the problems of authentication (the user is really who he declares to be), authorization (the user is allowed to do what he or she is requesting to do), confidentiality (the right information is only transmitted to the right person), data integrity (recorded data are valid), and action tracking (every manipulation is signed and recorded in case of conflict) are of paramount importance.
5. The control component (the conductor) allows to optimize task management and to eventually distribute the requests on different information servers. In that particular domain, emphasis is currently put on the development of intelligent agents, which task is to retrieve relevant information on the Net from the various servers that might reference it. In such an environment, parallel requests are issued asynchronously with the user work [39], being prompted only when the answer is made available.
6. Other components are more specific of a domain or of categories of users. This concerns statistical packages, local image processing, biosignal processing, decision-support tools or a natural-language processor for automatic text indexing.

In a different and newer approach, where the network is the system ("client/network approach"), those components (at least those functions) are retrieved in a particular server, that acts as a unique front-end for the network computer. Depending on the information willing to be accessed, the server serves its client or forwards the request to another server (either local or remote). In the second case, when the requested information is made available, the front-end server is responsible for formatting the retrieved information in a common standardized way. This architecture, which is the foundation of Intranet developments, allows the client workstation to be as simple as possible since it has only to deal with a single server presenting information in a single formalism, and has no more to be able to "speak" with a collection of heterogeneous servers (Fig.1).

Figure 1. Network computer-based architecture.



5. Integration Aspects

From previous discussions, it appears that the concept of a workstation can be instantiated in some flexible presentation (i.e., from a notepad to a powerful multimedia workstation or a network computer) and eventually complex to implement and maintain (i.e., largely determined by the underlying architecture of the information system). Indeed, at least three aspects of integration of a workstation can be considered [9].

5.1. Functional Integration

Functional integration is of immediate concern for the end-users of the workstation. The objective is the clear definition, for each category of users of the required functionalities (i.e., what the workstation should provide), and they should be made accessible (i.e., how the workstation should present functions and their dynamic binding). A typical example is the integration of desktop publishing functions with more traditional HIS functions (e.g., appointment and scheduling, act management, medical-record management). For example, a summary report, directly accessible through a spreadsheet or a text editor can be produced from the integration of answers to queries on distributed servers. If some error is found, the end-user should be able to update transparently both the report and the original data on the servers. This problem is particularly relevant in Intranet-based applications where information can be generated as HTML pages from the servers without easy feedback on the source data.

5.2. Technical Integration

Technical integration relates to the way the different components of the workstation constitute a coherent environment. It can be considered from five dimensions: presentation, data, communication, control and semantics.

1. *Presentation integration* tries to guarantee that the different tools accessed by the workstation have a common appearance and behavior. Presentation integration is achieved through the use of local and/or institutional style guides.
2. *Data integration* means the capability, for the end-user, to perceive the information as if it was stored in a single database, when there are in fact distributed databases on multiple servers. This is particularly true for the patient's record.
3. *Communication integration* relies on the standardization of the messages exchanged between the station and the different servers.
4. *Objective of control integration* is to allow interworking of the different applications on the workstation (i.e., in sequence or in parallel) [51].
5. *Semantic integration* still represents the critical issue. Meaning of medical concepts should be unified for enabling the applications to exchange information. A metathesaurus such as the UMLS is useful to establish links between a concept extracted from a given nomenclature (e.g., MESH, ICD10, SNOMED International) and entry points to data and knowledge banks. However, no metathesaurus will exactly match the precise needs of any institution in terms of concept- and object-modeling. Within an institution, semantic integration is facilitated by the constitution of a global data dictionary and the development of a vocabulary/terminology server that allows for mapping between the information coming from various sources [54-56].

5.3. Organizational Integration

Organizational integration refers to the way the workstation can become part of the enterprise-information system, can facilitate the collaborative work of the health-care professionals, increase quality and performances and enable evolution and changes at the institutional level. Installation of an intelligent workstation should, therefore, be part of the general strategy of the enterprise. At an institutional level, this implies [2,57]:

- the clear definition of a migration strategy;
- the selection of an appropriate network infrastructure supporting wide-area connectivity;
- the installation of applications that support standardized application-programming interfaces (API) and system-independent repositories (client/server applications);
- an institutional commitment to promote and respect standards [47];
- procedures to check the conformity of the application to selected norms and standards, and to insure quality; and
- the organizational and financial investments needed to provide for the necessary training of the end-users, to promote collaborative work, and to create a dynamic environment for change.

6. Evaluation Criteria

Establishment of a reference list of evaluation criteria might be relevant in different situations [58,59]. During the development process, a list of criteria can serve as internal validation, for example, to avoid deviations from intended objectives. In this case, the list should be defined *a priori* and internal validation should be completed by independent evaluators.

At a management level, evaluation can help with the selection of the most appropriate workstation strategy (from a comparative study of scenarios) and with determining the impact of the installation of workstations in a given organization (e.g., cost-effectiveness evaluation). Intuitive perceptions of increased productivity, as claimed by vendors or perceived by end-users, have to be balanced with direct measurements. This is particularly difficult since counterproductivity may be expected with the introduction of a new tool, and the learning curve may differ with different workstations or categories of users.

Table 3, from [53], gives some examples of criteria relevant to the evaluation of a workstation for the health professional. The extent to which functions are covered (what the workstation does) and integrated (functional integration) is of immediate concern for end-users.

At a technical level (i.e., how the workstation functions are implemented), conforming with software-engineering principles (e.g., modularity, re-usability, modularity) are important to guarantee accepted and perennial applications.

Organizational criteria should be distinguished when one is analysing the result of a workstation experience and what can be attributed to the tool and to its environment. Similar complex interrelationships obviously appear for medical, cultural or ethical criteria.

7. Discussion and Conclusion

The multimedia workstation for health-care professionals, integrated in a network architecture, is the natural bridge to distributed and integrated health-information systems and offers the support for telemedicine and collaborative work in the health area through exchange with other professionals of the domain. Medical decisions rely on consultation of the patient record, analysis of similar cases, and access to contextual knowledge. The workstation allows the end-user to view the patient record as a single entity when the information is distributed among different servers. Automatic coupling between medical-record coding and data/knowledge query systems facilitates the search for contextual knowledge and the selection of similar patient cases already stored in databases.

Part of the difficulty in the development of an intelligent workstation is related to the management of multimedia medical objects that are expressed with multiple formalisms and reside on heterogeneous machines. This requires the use of collections of dedicated tools and their integration in the common workstation platform. Re-use of existing software components is essential, since major elements already exist in the marketplace and cannot be rebuilt from scratch. But integration and re-use might be conflicting goals [10]. For example, the success of office-integrated products (e.g., combination of a word processor, a worksheet, a graphics system, and a database) is in contradiction with modularity, which is a condition for re-use. Constitution of a meta-database (e.g., through an object-oriented model) facilitates the transparent access to heterogeneous information repositories and semantic integration [40,41], but limits the dynamic inclusion of new components (i.e., new data structures have to be declared in the meta-database to be transparently accessed). Security issues have still not been solved [50].

Networks of care delivery are dynamically evolving and are geographically dispersed. These forces are causing the facility-centric view of care to change and, hence, our strategies for managing the clinician's desktop must change. In our past environment, we defined the workstation not only by its functionality, but also by its hardware. When a society accepts to spend 2000 to 3000 US$ per year and per inhabitant for health care, investment of a single workstation for the cabinet office of a physician that provides both local processing capabilities and communication capabilities cannot any more be considered as an economic barrier. The situation is not the same at a single mid-sized facility, such as a 500-bed teaching or city hospital where their might be 5000 desktops. Rapid developments in software and hardware make each instance of the workstation obsolete if not at the time of deployment, then certainly within three years. Considering that workstations currently cost about $2500 to purchase and some have estimated that each workstations costs over $5000 per year to support, the current approach to hardware deployment in a mid-sized facility is over $4 million annually for purchase and replacement and up to $25 million annually for support before considering the costs of any applications. In this case, the emergence of Intranet technology along with programming techniques, such as Java that allow the desktop client to remain simple, raise the promise of less expensive and less complex hardware to support the workstation enterprise functionality.

A major difficulty remains in the fact that an intelligent workstation (either a PC or a NC) is something to add to an existing information system, acting as a mediator between the end-user and the underlying information system. For an institution, installation of intelligent workstations is different from the purchase of a set of microcomputers or graphics stations. Decision makers should be convinced about the necessity of a clear migration strategy and conscious of the importance of the educational and organizational investments that are required. Experiences with collaborative development of workstation components and promotion of re-usable software libraries are two areas where substantial progress might be expected.

Increasingly, sophisticated technological solutions for socio-political problems are unlikely to be successful unless the underlying socio-political problems themselves are addressed without the technological veil. The multimedia health-professional workstation will not, by itself, solve health-care crises, reduce costs, or even improve care. The workstation, when properly conceived, is an integration tool that allows information technology to flexibly follow the strategic needs of the organization while, at the same time, leveraging the clinician's use of the global health-knowledge network.

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Table 3. Categories of criteria.

Categories of criteria	Main actors	Questions
1. Functional - Functional coverage - Functional adaptability, etc.	End users	What?
2. Technical *Architectural* - Extensibility, evolutivity, maintainability, etc. - Modularity, distributivity, portability, openness (e.g., standards), interoperability, reusability, etc. - Degree of integration (presentation, communication, data/knowledge, control), etc. *Quality and performances* - Acceptability, ease of use, time response, reliability, security, etc.	Engineers	How?
3. Organizational - End-users' participation, - Support for group decisions, - Changes in the relationships between actors, etc.	Decision makers	Which consequences?
4. Medical - Quality of care, - Medical efficacy, effectiveness, etc.	Patients, health professionals	Improved quality of care?
5. Cultural and ethical - Educational and research value, - Auditability, patients'/professionals' privacy, etc.	Society	Which values?
6. Economic - Direct and indirect costs, - Return on investments, etc.	Decision makers	Which resources?
7. Industrial and commercial - Industrial commitment, investments, - Market identification, market share, etc.	Industrials	Which perspectives?

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