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FOR BIOMEDICAL COMMUNICATIONS

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MD on Tap: Point of Care Information Delivery;
A Report to the Board of Scientific Counselors

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1. Background

In the past decade, the growing interest of clinicians in Evidence Based Medicine (EBM) has been accompanied by advances in two key technical areas: powerful real-time information systems and wireless handheld computers. These technologies have given health care providers tools to facilitate the practice of EBM, especially the ability to access information at the point-of-care. As a result, handheld computers and wireless networks are becoming important information adjuncts for mobile health care providers. However, the typical user interfaces to common sources of medical information, such as PubMed,[1] The National Guidelines Clearinghouse[2] or Cochrane Reviews,[3] do not render well on a small screen. Additionally, the amount of formatting and other data transmitted to generate these interfaces can slow the response of today's wireless devices which typically receive data at line rates of 11 Mbps for WiFi[4,5] (802.11b), or less for smartphones. Finally, because such sources are designed for browsing, they often require time or skill to find pertinent information for the point of care scenario.

Healthcare providers, especially younger clinicians, residents and medical students, are increasingly adopting the use of handheld computers for access to a variety of information sources.[6,7,8] The handheld computer hardware, operating systems, peripherals, communications and input modalities are all in flux, with each new generation of device boasting improved performance and usability. Providers of online information resources, such as MEDLINE, will need to employ well-founded design principles to effectively serve mobile healthcare providers over the wide and changing handheld computer platforms available. Although PubMed is highly successful in delivering MEDLINE citations and other information to researchers, it may require modifications to be optimized for mobile health care providers.

Aware of the momentum for more and better access to medical information via handheld computers, the Lister Hill National Center for Biomedical Communications Board of Scientific Counselors endorsed research related to wireless handheld computers in May 2002: "PDA's have become the 'peripheral brains' of essentially every physician in training in the country, and NLM can ride this wave of popularity to modify information access behaviors of a whole generation of new healthcare professionals if it acts promptly."[9] and in September 2004: "Wireless hand-held personal digital assistants (wPDAs) are viewed by the Board as an absolutely critical component to the timely and efficacious delivery of health care and health professionals should be the focus of this work. In this regard, it is imperative that the NLM investigate wPDA technology, its advantages, and its limitations."[10]

2. Project Objectives

The MEDLINE Database on Tap (MD on Tap) project was initiated to discover design principles for real-time point-of-care delivery of clinical support information via wireless handheld computers. We intend to learn how to present data so that busy clinicians can quickly find the most pertinent information, even when limited by the small screen and restricted bandwidth of handheld computers. To that end, we explore the following aspects of information systems:

Display and Navigation.

Information systems for small wireless computers require special consideration of both interface design and information content. It is not sufficient to merely scale the desktop computer interface for a smaller screen.

Information Organization and Content.

Busy clinicians do not have the luxury of being able to browse a large number of documents to find information directly related to their current point-of-care scenario. Information must be retrieved and presented to facilitate rapid selection of only that information that is both high quality and relevant to the clinical question at the point-of-care.

3. Project Significance

This project contributes to two of the overall goals stated in NLM's Long Range Plan 2000-2005.[11]

Goal 1: Organize health-related information and provide access to it; Objective 1.2, Provide access to biomedical information.

The proposed research addresses specific Program Plans to "improve NLM's retrieval interfaces" and support "different categories of users". Specifically, the project explores retrieval interfaces for handheld computers and support of mobile healthcare providers.

Goal 2: Encourage use of high quality information by health professional and the public.

This project addresses the specific Program Plan to "..strengthen the ability … to serve the full array of health professionals". It contributes to serving the growing number of mobile healthcare professionals who are adopting handheld, wireless computers as another information resource. Specifically, the MD on Tap project extends the reach of MEDLINE through our PDA clients and testbed system to these mobile healthcare providers as an adjunct to other PDA-based information resources.

Although the project focuses on delivery of MEDLINE data, the larger contribution is the discovery of general design principles for point-of-care medical information systems that can be applied to any point-of-care medical information system.

4. Methods

4.1 Testbed

Our research approach is to build a working system as a testbed, recruit users for the system, solicit feedback, and compile aggregate usage statistics to discover usage patterns and preferences.[12] We also hope to establish collaborations with individuals or institutions from whom we can collect more structured usage data. Our intent is to use the testbed to introduce and evaluate emerging concepts for information retrieval, display and navigation.

4.1.1 Design Criteria

We chose MEDLINE, NLM's premier database of bibliographic citations, as the dataset for the testbed for two reasons: 1) It is a well known and credible source of health-related information;[13]

2) The PubMed search engine and XML-formatted search results are available to third-party programs via the Entrez e-utilities.[14] Other testbed design criteria were: 1) Control the user interface; 2) Provide fast response; 3) Support user-specific preferences; 4) Do not require user login; 5) Collect aggregate user statistics; 6) Support results organization experiments.

4.1.2 System Design

Three designs were considered that would use the e-utilities for access to MEDLINE and support at least some control of the user interface. The designs, illustrated in Figure 1, are Client only, Intermediate HTML server, and Client plus intermediate server. Each design is briefly described:

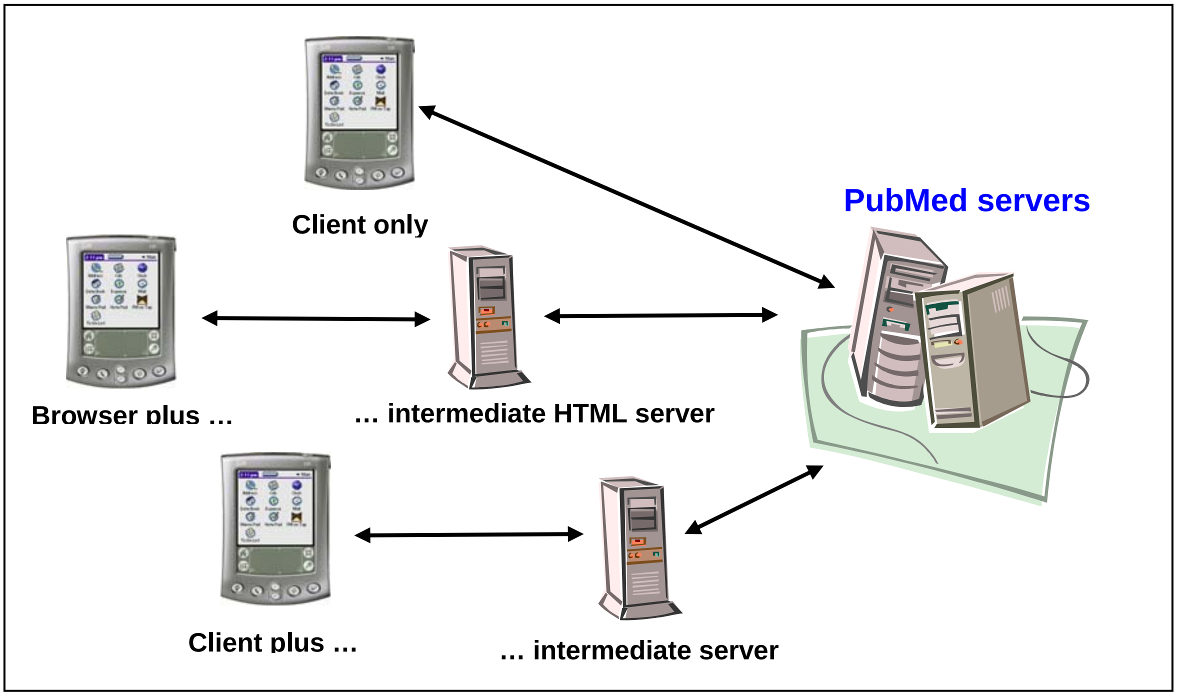

Figure 1. Three Considered Designs.

In the Client only design, the client program accesses PubMed directly, executing searches and retrieving results using the e-utilities. In addition to controlling display and navigation, the client is also responsible for parsing and manipulating data from PubMed. User-specific preferences can be implemented by the client and stored locally. Any results organization experiment would require a new client to implement the results organization. There would be no direct method for collecting aggregate statistics. Because data from PubMed can be in XML format, transmission speed should be reasonable. On the other hand, PDAs generally do not include powerful processors, so processing of the delivered data can contribute to overall latency.

In the Intermediate HTML server design, the PDA's browser program communicates with the intermediate HTML server that uses the e-utilities to communicate with PubMed and formats the results in HTML for the small screen browser. Because PDA browsers exhibit a broad range of styles and functionality, the data would need to be formatted for the least common denominator of these, thus limiting the ability to completely control the user interface. Aggregate statistics can be collected and stored by the intermediate server, but user preferences can only be implemented by requiring the user to log in to the intermediate server. Changes in data organization and display, including those to support results organization experiments, are accomplished at the intermediate server. Data delivered to the browser must include HTML overhead resulting in a larger amount of data transmitted. Data processing by the intermediate server can introduce a small latency.

In the Client plus intermediate server design, the client communicates with the intermediate server that uses the e-utilities to communicate with PubMed. Although the client is responsible for data display and user navigation features, the server handles the bulk of the data processing and organization tasks. The server can collect aggregate statistics, while the client can store user preferences without the need to log in. Changes in data organization can be accomplished at the server, while changes in data display require a new client. Only tagged data needs to be transmitted between client and intermediate server, so transmission speed should be reasonable. Data processing by the server can introduce a small latency.

In addition to the factors just discussed, an important disadvantage of using a client application rather than a browser is that in today's environment the client cannot be platform-independent. There are two primary PDA Operating Systems, Palm and Pocket PC, plus the increasing popularity of Research in Motion (the Blackberry) and various smartphone operating systems. There is currently no programming language or environment that supports all necessary aspects of development for all devices. However, most handheld computers with Internet connectivity include a browser that manages the individual requirements imposed by the platform and the operating system.

Table 1 summarizes the advantages and disadvantages of the three designs.

Table 1 - Pros and Cons of Three Prototype Designs

Design	Pros	Cons
Client Only	1. Control of user interface 2. Able to store user-specific data locally	1. Not platform independent 2. User must install new version when client changes 3. Client must do all data processing 4. No opportunity to directly monitor performance or gather aggregate usage statistics
Intermediate Web Server	1. Platform independent 2. Changes for new versions implemented at the server only 3. Can perform data processing at server 4. Can monitor performance and gather aggregate usage statistics 5. Can store queries, results, citations at server to improve performance	1. Little control of user interface 2. Must store user-specific data at server, requiring user identification 3. Html file ~4 times the size of equivalent XML data

Client plus Intermediate Server	1. Control of user interface 2. Able to store user-specific data locally (no login needed) 3. Can perform data processing at server 4. Can monitor performance and gather aggregate usage statistics 5. Can store queries, results, citations at server to improve performance 6. Only need to transmit data to be displayed (XML data) 7. Can quickly respond to changes in back-end servers.	1. Not platform independent 2. User must install new version when client changes

The client plus intermediate server was selected as the best overall design for the testbed. The client program permits tight control of the user interface and local storage of user preferences while the processing power of the intermediate server supports experimenting with methods to facilitate precision and improve response. Together these allow for fast performance plus flexibility in those aspects of information delivery that are being researched.

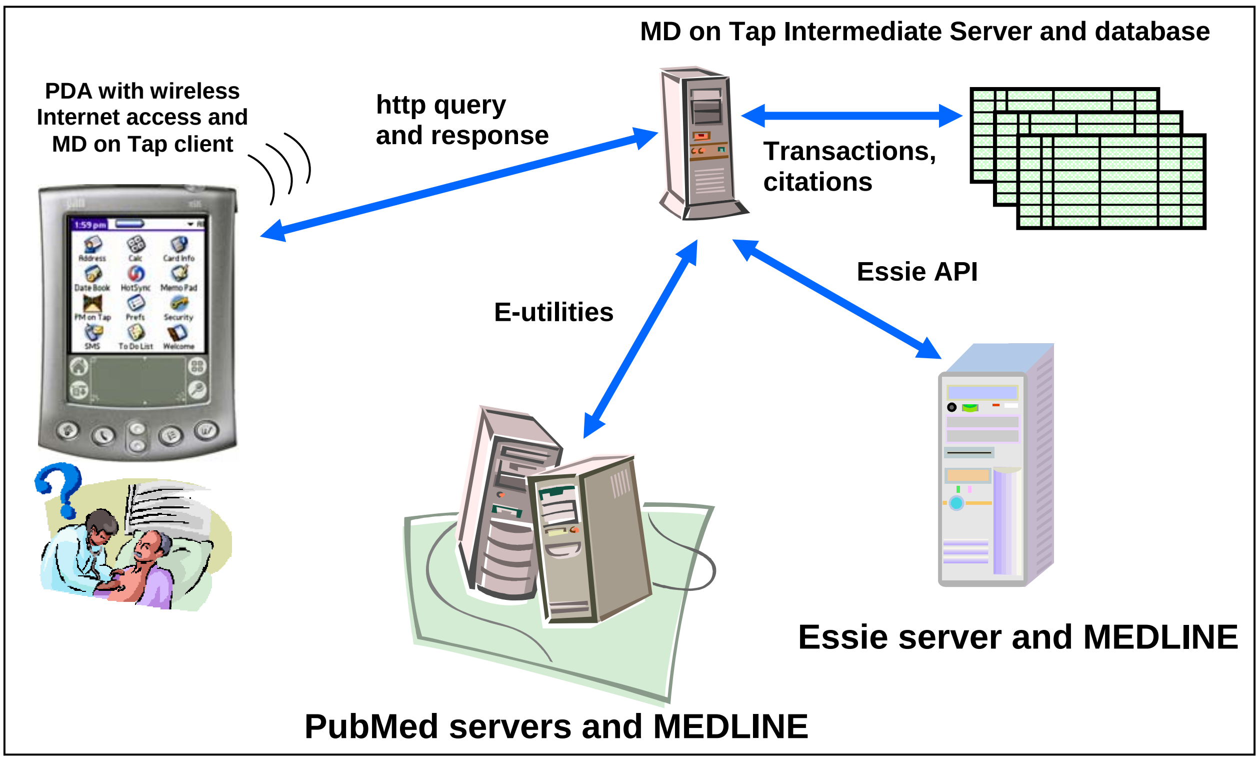

Figure 2. MD on Tap System Design: client plus intermediate server with MEDLINE datasource.

A diagram of the testbed system is shown in Figure 2. Initially, the system used only the PubMed search engine via the e-search e-utility. The recent inclusion of the optional Essie search engine shown in Figure 2 is discussed in sections 4.2.2 and 5.2.2.

Because the intermediate server represents a potential bottleneck to fast service, efficient server design is crucial to the overall performance. Because of its scalability, redundancy and security features, UNIX was chosen as the appropriate operating system for the intermediate server. The servlet that receives and processes transactions from MD on Tap Clients is written in Java 1.4 and runs in a Tomcat 5.0.27 container on an Apache http server on a high performance UNIX system. The servlet employs a connection pool to handle multiple simultaneous sessions. The intermediate server includes a mySQL database in which are stored recent queries, recently requested citations and user transactions. The queries and their related citations are kept fresh for 15 days by an Update program that executes early each morning. User transactions are kept indefinitely. The user's IP is converted using a lossy, thus irreversible, encoding scheme and becomes part of each saved transaction. This scheme permits our analysis programs to identify groups of transactions as belonging to one user, yet ensures users' anonymity.

4.1.3 Testbed Development Milestones

A direct consequence of our research approach is development of features and system components either requested by users or learned from observations of aggregate users' behavior. Figure 3 illustrates with screenshots and a timeline the versions of MD on Tap that have been introduced since the project began. Two milestones are worth mentioning here:

Starting with Version 1.5, the client sends a version tag with each transaction. This permits correlation of aggregate user behavior to the features available in each version, for versions 1.5 or greater. It also provides a mechanism to alert non-registered users to the availability of a new client: the intermediate server recognizes search query transactions received from an older client and includes a message about the new client as the first "result."

The original name of the client and the system was PubMed on Tap. This name is seen in screenshots in Figure 3 and various screenshots in other sections of this report. To emphasize the aim of the project as better access to information, rather than an extension to PubMed service, the project was renamed MEDLINE Database on Tap (MD on Tap) with the recent release of Version 1.7 clients. The new name not only more accurately reflects the focus of the project, it also opens possibilities for incorporating non-PubMed components, such as results clustering and alternate search engines, without misleading our users.

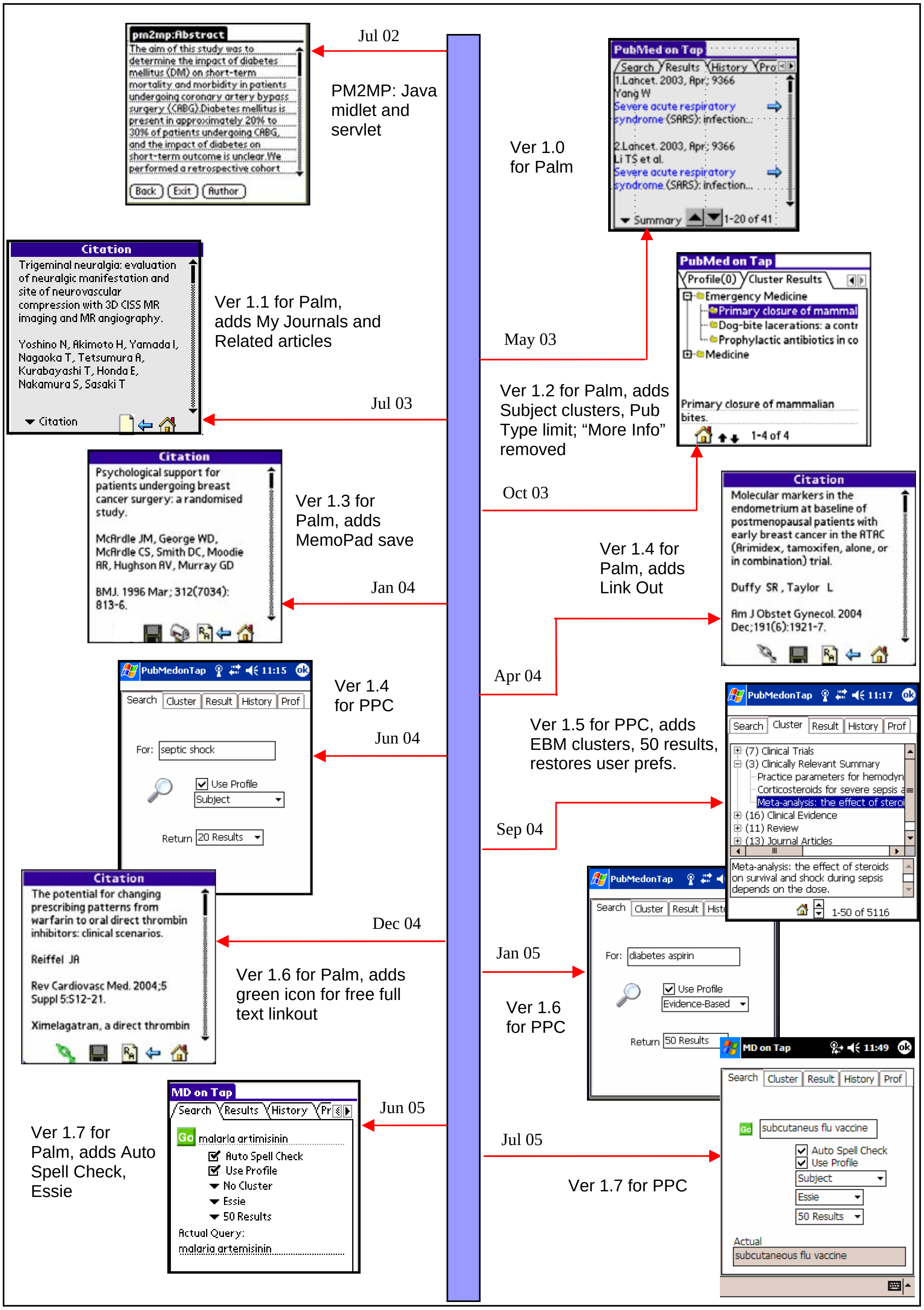

Figure 3. Development milestones.

4.2 Client

4.2.1 User Interface Design Considerations

The success of the project methodology depends on being able to recruit and keep MD on Tap users who are mobile healthcare professionals. Potential users, especially younger clinicians, are typically computer savvy and technically aware, and they expect a pleasing and useful interface to a reliable system. To attract this target group, it is imperative to initially present a well designed user interface, even though our goal is to discover the principles of such an interface.

In July 2002 we developed an exploratory Java midlet client, using the user interface controls available through the J2ME[15] software package. The client ran on the Java virtual machine (KVM) available for the Palm operating system, communicating with a UNIX-based servlet using http communication protocols. Although the client efficiently performed the desired functions of searching, displaying search results and fetching and displaying individual citations, control of the look and feel of the user interface was restricted by the limited controls available through J2ME. Invited observers were pleased with the fast response of the system, but found the interface unattractive and citations difficult to read. Thus we verified early in the project that functionality alone was insufficient.

Late in 2002 we began development of a client for the native Palm operating system. At that time, Palms were the choice of the majority of health care providers who used PDAs. The Palm client program is written in C/C++ using the Code Warrior development environment. The client uses the PDA's wireless communication interface and the http protocol to communicate via the Internet with a servlet on the intermediate server. At that time there were no authoritative references to guide user interface criteria for handheld computers, so we relied largely on common sense. To present a familiar-looking interface to new users, the design of the client user interface is modeled in part on ePocrates,[16] a drug database application for PDAs that is popular among healthcare professionals. For readability, we also strived for the uncluttered look of the Google search page. Following this model, functions are organized by tabs and drop down lists are used where possible to save space. Each aspect of the user interface required consideration of the space available on a standard 2" x 2" PDA screen, the readability of text, and the number of taps required to execute a choice or navigate to a new location. Although vertical scrolling is sometimes necessary, horizontal scrolling, with one exception, is eliminated. Small evocative icons were designed and used in favor of larger text-filled buttons whenever possible.

To the extent that project resources and platform constraints permit, we have added features most requested by users. We have also removed features that were rarely used or presented a possible security problem. The tradeoffs between desired features and reasonable implementation and between simplicity and power are a constant consideration. Many potential users requested a client for the Pocket PC operating system. A client for the Pocket PC was developed and released to the public in June 2004. The Pocket PC client is written in C/C++ using the Microsoft eMbedded Visual C development environment. One notable challenge of the development was maintaining the same look and feel across the two very different PDA operating systems, using two different development environments.

4.2.2 Client Features

Notable features introduced over several versions include:

1. Several PubMed search limits, including clinical queries, journal subsets and publication type (see Figure 11). These are selected on the Profile tab. We also added the combination of English and Human as a single limit, thinking that would be useful in limiting the search to clinically-oriented articles. The downside to using most limits is that they are only effective if the article has been indexed.
2. Several options for dealing with individual citations (see Figure 7). The citation can be saved in the PDA as a text file by tapping the disk icon. Similar articles, as determined by a PubMed's Related Articles algorithm,[17] are returned by tapping the "RA" icon. If the PubMed citation includes a link to the full text of the article, a link icon appears at the bottom of the Citation screen. A green icon indicates the article as being among the set of "free full text" articles. When the link icon is tapped, the MD on Tap client launches the PDA's browser with the URL provided by PubMed. At this point, MD on Tap is no longer the active application. Because the Palm OS can only run one program at a time, MD on Tap closes when it launches the browser, and the user must restart MD on Tap to resume searching. This is not an issue with the Pocket PC.
3. Two results clustering options. Search results can be organized either by topics (subject areas of the journal in which the article is published) or the potential strength of evidence in the reported study. Clustering by topic is based on the expanded *Alphabetic listing by subject field* section of the list of 4,500+ journals being indexed for Index Medicus®.[18] The list of subject areas is augmented with the set of controlled descriptors used for indexing journals according to discipline in NLM's Indexing Initiative,[19] Clustering by strength of evidence is based on EBM recommendations as implemented in the strength of evidence taxonomy (SORT),[20] MeSH and Publication Type indexing is used to assign citations to the potential highest strength of evidence level. Figure 4 shows selection of results presentation and three available results presentations: in a list ordered by date, clustered into subject areas, and as strength of evidence pyramid.
4. An Auto Spell Check option. In 2005, NCBI introduced a new e-utility, E-spell, which offers suggested alternate spellings for queries containing unidentified terms. Our most recent MD on Tap clients include an Auto Spell Check option on the Search tab. If the Spell Check option is selected and E-spell offers an alternative spelling, the latter is used to search MEDLINE. Terms actually used in the search are displayed at the bottom of the search screen and are stored on the History tab, as shown in Figure 5.
5. Two search engine options. In addition to well-known and widely used MEDLINE access via PubMed services, our client provides an opportunity to test Essie, a new probabilistic search engine developed at NLM. Figure 6 provides side by side views of the top citations retrieved by the two search engines.

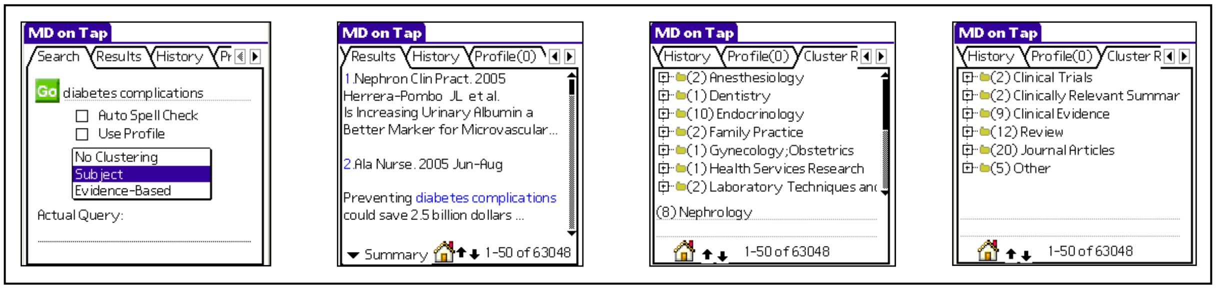

Figure 4. Setting results option, three results organizations.

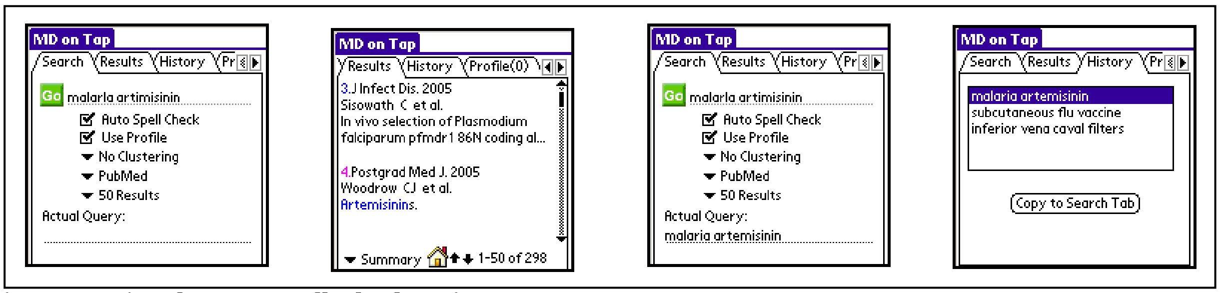

Figure 5. Using the Auto Spell Check option.

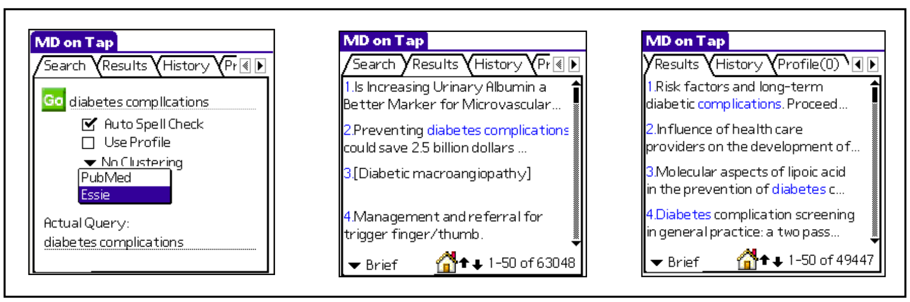

Figure 6. Selecting Essie, top four results from PubMed and from Essie.

4.3 Analysis Tools

All transactions between client and intermediate server are recorded in the intermediate server database. The transactions are queries (searches), citation retrievals and Related Article links. Additionally, more recent client versions notify the intermediate server for Save-Citation or LinkOut-to-full-text events. In addition to the content of the transaction request string, the database record includes the date/time of the transaction, the amount of time for the intermediate server to process and respond to the transaction request, the client operating system and version number and the de-identified user ID. Prior to the lossy encoding of the user ID, the country code is extracted and included in the database with the transaction details. Specially developed software uses the de-identified user ID and date/time fields to group transactions into user sessions for automatic generation of aggregate statistics or for manual analysis of user behavior.

4.4 Feedback Conduits

We offer two mechanisms for our users to opine on the system, or just contact us with questions: an MD on Tap email address and a forum. Our users have employed these to ask questions of the developers or to resolve problems, and for occasional thoughtful comments or kudos.

One of best methods for eliciting feedback is live interaction with individuals using MD on Tap in real time. Toward this end we conducted a small usability study and have demonstrated MD on Tap one-on-one in the exhibits area of the Medical Library Association 2003 and 2004 annual meetings, the Association of American Medical Colleges 2003 annual meeting, the 2004 IEEE Symposium on Computer-Based Medical Systems, and to various visitors to NLM. In July, 2005, we participated in the LHNCBC open house given in association with the NLM Training Conference, demonstrating MD on Tap one-on-one to interested individuals.

We have sought and continue to seek collaborators in medical institutions with whom we can conduct structured evaluations of the ability of MD on Tap to provide useful information at the point of care.

5. Evaluation

5.1 Usability Evaluation

5.1.1 Usability Study

In July 2003, we had the opportunity to test an early Palm OS-based MD on Tap at the National Cancer Institute's Usability Lab with nine volunteers from a variety of backgrounds. Details of this study are reported in Alexander.[21] Direct observation of naïve users of MD on Tap was invaluable for uncovering confusing interface aspects and difficult navigation functions. Three changes to the client were immediately implemented as a result of the study:

1) Design principle learned: Retain the icon functionality of the equivalent desktop application. Knowing that the Related Articles link was popular among PubMed users and available via the e-utilities, we incorporated a link to Related Articles from citations displayed in PubMed on Tap. In PubMed, the link is indicated by the text "Related Articles," which would be too large to display on the handheld computer screen. As shown in Figure 7, we chose an icon depicting a blank page as the link to Related Articles. The blank page was similar to the icon used by PubMed to indicate that a citation does not include an abstract and was also a link to the citation. This confused users because they were often looking at the text of an abstract on the same screen as the icon they had associated with no abstract available. The next version of MD on Tap used a similar icon, but with the letters RA superimposed.

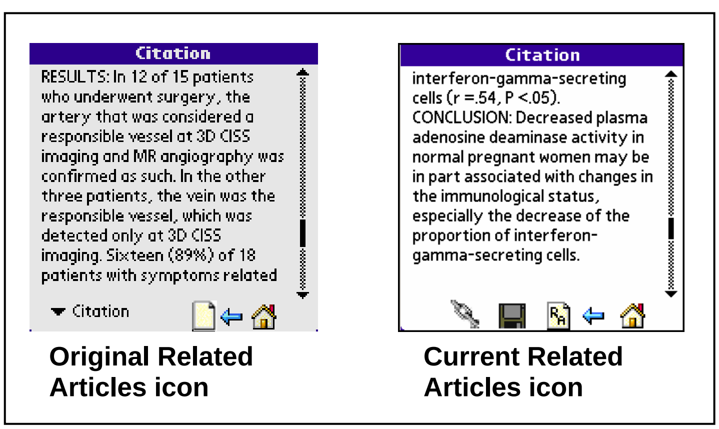

Figure 7. Evolution of the Related Articles icon.

2) Design principle learned: Provide a straight navigational path to the primary target information.

MD on Tap delivers and displays only a Summary of each citation in the search result list, consisting of the publication, first author and up to two lines of the title. Thinking that users may want to know more about an article before investing in the time to retrieve the entire citation, we offered a quick More Information link to display the complete author list, the Subject listing of the journal in which the article is published, the MeSH terms assigned to the article, and a field we named Key Concepts which we set aside for future use, with the goal of displaying an automatically extracted summary of the abstract text. This data had been transmitted along with the original Summary text, so could be displayed immediately if the user tapped the blue arrow. As shown in Figure 8, the interface was designed so that tapping the blue arrow would bring up the More Information screen and tapping the Summary text would fetch the entire citation from the intermediate server. The primary flaw in this concept is presenting data that is tangential to the primary information goal, in this case the citation, and thereby adding complexity to the overall task of finding information. Users are not initially interested in supplemental data; users want to read the citation. The secondary flaw was choosing an enticing blue arrow as the link to the supplemental data. Users invariably tapped the arrow expecting to see the citation. The blue arrow and More Information were removed from the next version of MD on Tap. A side benefit of removing the arrow is the additional space available for displaying the title.

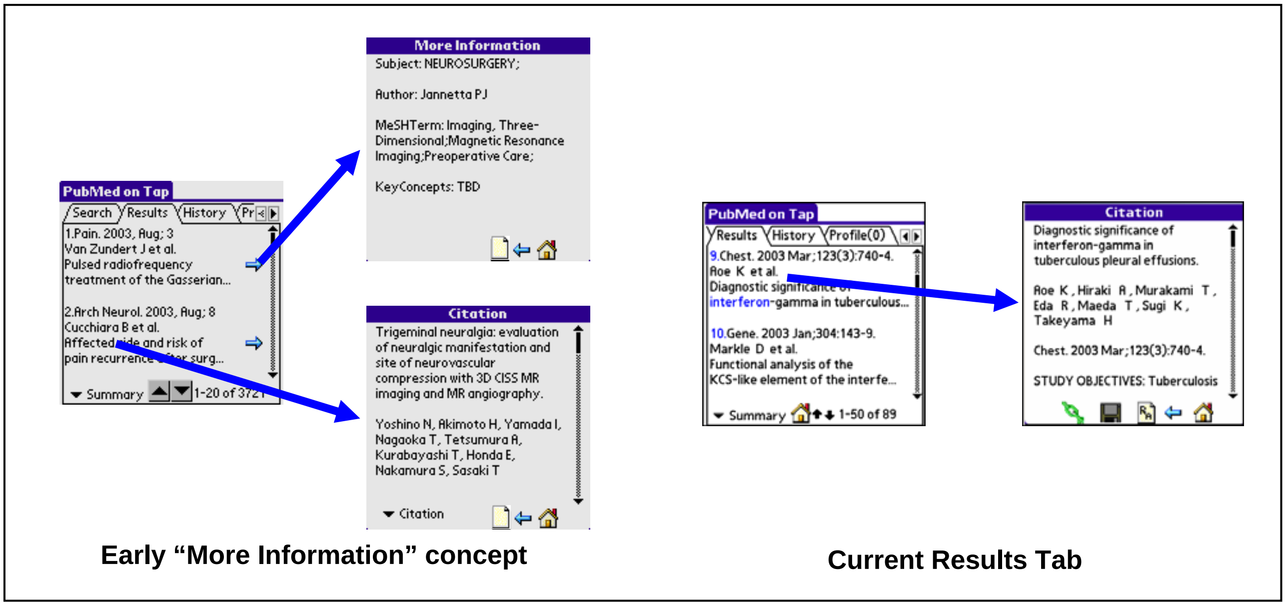

Figure 8. Changes in the Results screen.

3) Design principle learned: Use simple visual prompts as memory aids; imitate WWW conventions when it makes sense to do so.

When a user taps anywhere on the Summary text on the Results tab, PubMed on Tap fetches and displays the citation on a new screen. Tapping the blue back arrow closes the Citation and returns to the Results screen. In the early version of PubMed on Tap, there was no indication on the Results screen that a given Citation had been viewed. Users did not always remember which Citations had been visited and often re-fetched the same Citation. In subsequent versions, the number associated with Summary on the Results screen changes from blue to pink when a Citation has been fetched. This simple visual clue is sufficient to remind users of what they have investigated and mimics what they have come to expect from web-based applications.

We also learned that what we considered to be ubiquitous icons did not always translate to the new application. Two examples from an early version are shown in Figure 9. Although it is known that selecting an appropriate icon for a verb is difficult, we chose a magnifying glass as the icon to tap in order to execute a search. The magnifying glass is used as a metaphor for "search" in many applications and we placed it near the search term entry field in the center part of the search screen where the gaze naturally falls. Nonetheless, although users remember this after they have used it once, most need to be guided to the magnifying glass on first use. MD on Tap always opens to the Search tab. We put a house icon on other tabs as a way to jump quickly to the Search tab, thinking it was functionally equivalent to a web site's "home page." Although the navigation did not confuse users, the icon, along with "PubMed" in the application name led some users to assume that they were using a browser. Although neither of these icons was determined to be a significant impediment to use, they represent a learning step.

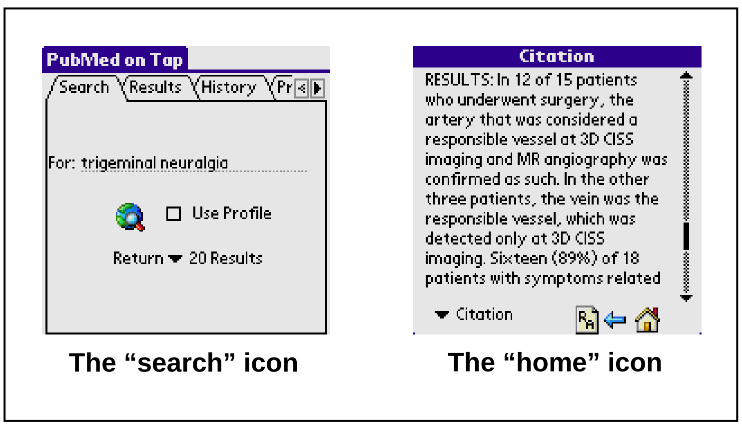

Figure 9. Ubiquitous icons.

Not all discoveries were negative. Users were generally pleased with the speed with which results and citations were returned, and thought the application was useful. Two users stated a preference for the Brief mode as an option for displaying results, rather than the Summary mode. In Brief mode, the only data displayed for each result is up to two lines of the title, thus permitting more results to be viewed at a time. Demner-Fushman[22] has found that title alone is frequently sufficient for determining if an article is clinical or non-clinical.

5.1.2 Other Face-to-face

We have found that the best way to demonstrate MD on Tap to one or a few people is to give them one of our PDAs and guide them, if necessary, through their own search. Most people are surprised and delighted with the quick response. Because the client handles all formatting and navigation, only tagged text needs to be transmitted between client and server, thereby achieving reasonable response time over the typically low bandwidths offered by wireless networks. An example of the difference in the amount of data transmitted is illustrated in Figure 10. The text on the left is returned from the text only version of PubMed for the summary text of one article.

The text on the right is the equivalent data transmitted to MD on Tap for the same article. In general, MD on Tap transmits less than 25% of the equivalent data from the text version of PubMed, an important consideration for computers that normally use low-bandwidth communication channels.

Data from PubMed, text version, for the first article of 20 results (24,012 characters for the whole page):


```
<dl><dt><table cellpadding="0" cellspacing="0" width="100%"><tr><td
nowrap valign="top"><b>1: </b></td> <td width="100%"><font size="-1"><a
href="/entrez/queryd.fcgi?cmd=Retrieve&db=pubmed&dopt=Abstract&list_ui
ds=15542987">Is the management of dog bite wounds evidence based? A
postal survey and review of the literature.</a></font></td> <td align="right"
nowrap valign="top"><SPAN><a CLASS="dblinks"
href="http://www.ncbi.nlm.nih.gov/entrez/queryd.fcgi?db=pubmed&cmd=Dis
play&dopt=pubmed_pubmed&from_uid=15542987">Related Articles,</a>
<a CLASS="dblinks"
href="http://www.ncbi.nlm.nih.gov/entrez/queryd.fcgi?cmd=Retrieve&db=pub
med&list_uids=15542987&dopt=Books">Books,</a> <a CLASS="dblinks"
href="http://www.ncbi.nlm.nih.gov/entrez/queryd.fcgi?cmd=Retrieve&db=pub
med&list_uids=15542987&dopt=ExternalLink">LinkOut</a></SPAN></td>
</tr></table></dt> <dd><font size="-1">Chaudhry MA, Macnamara AF,
Clark S.<br>Eur J Emerg Med. 2004 Dec;11(6):313-7. Review. <br>PMID:
15542987 [PubMed - indexed for MEDLINE]<br></font></dd> </dl>
```


Data from MD on Tap for the first article of 20 results (4388 characters for the whole page):


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<PMID>15542987</PMID><AUTHOR>Chaudhry  MA  et
al.</AUTHOR><TITLE>Is the management of dog bite wounds
evidence based? A postal survey and review of the
literature.</TITLE><JOURNAL>Eur J Emerg Med. 2004
Dec;11(6):313-7.</JOURNAL><AUTHORLIST> </AUTHORLIST>
```


Figure 10. Data transmitted by PubMed and by MD on Tap for one article summary.

5.1.3 User Access, Registration, Forum, E-mail

MD on Tap clients are freely available for download from our project website, http://mdot.nlm.nih.gov/proj/mdot/mdot.php. Although not required for download, visitors to the website are invited to register for email updates about new versions or other news. The only required field on the registration form is the recipient's email address, but we invite them to tell us a few things about themselves (name, affiliation, position) and their PDAs. We currently have over 350 registered users.

Our users are also invited, via links on our project web page, to contact us through the project email address or the forum. They use these mechanisms primarily to ask for help with installation or connection problems, and occasionally to offer genuine feedback and thoughtful critique. User suggestions are weighed along with project resources and goals during the design phase of the next version of the client. Examples of modifications in response to user suggestions are:

- Create an installation program for the PPC client that creates a shortcut icon for MDoT under Programs.
- Highlight search terms in the results list.
- Add an "English + Human" search limit checkbox to support the Evidence Based Medicine results clustering option.
- Include clearer terms for PubMed Clinical Query category, i.e "Therapy+Broad" rather than "Therapy+Sensitivity".
- Add a menu (on Palm GUI) as an alternative to left/right arrows for moving among the tabs.
- Default return is 50 results, rather than 20 results.
- Reinstate last-used selections for Profile and for Search options on startup.

Of course, our favorite responses are the kudos:

- "Thank you for creating this resource! It is a wonderful step forward towards mobile access to pertinent clinical and educational information." J. Jacobs, MD, January 2004.
- "I actually find the program quite useful. I now have a resource at the bedside." T. Mixter, MD, June 2004.
- "The NLM team is to be congratulated on its release of a wireless-PDA program to access Medline. …I can recommend its clinical use right now." P. Goodman, MD, June 2004.
- "…this promises the holy grail of pubmed on the sidewalk and elevator and cocktail party. This could get interesting. Bring it on!" B. Fish, MD, September 2004.
- "Very fast stable and in many ways more useful than pubmed. I'm delighted." J. Topf, MD, December 2004.
- "…it works exceedingly well, and I am doing PubMed searches on the run several times a day." S. Simpson, MD, June 2005.

And finally, a testimonial by Dr. Simpson: "I have tried it, and I'm loving it. As I intimated in my last email. Those of us who desire to practice evidence based medicine find use for it right at the bedside. It sure beats what I used to do:

Early in my career... write down on a 3 x 5 card what I need to look up at home Later... write down in my Palm, then Pocket PC Later still... find a computer on the ward and use Medline and other resources to answer the question now Now... stand at the bedside, do a lit search, find recommendations, discuss with the patient where they come from and how trustworthy they might or might not be

Which of those doctors would you prefer to have caring for you in hospital?"

5.1.4 User Observation (transaction-based)

Special software has been developed to analyze the transactions stored in the intermediate server database and group transactions into user sessions using the de-identified IP address and the date-time stamp of the transaction. A session consists of 3 or more transactions from the same de-identified IP address, with no two transactions separated by more than 15 minutes. A transaction can be a MEDLINE search query, a request for a citation, a save-citation event or a linkout event. Although the save-citation and linkout events are performed locally on the PDA, the client sends a notice of the event to the intermediate server. We nominally consider either of these events to be an indication that the user has found a citation of particular interest.

Unless otherwise noted, information results in this section are extracted from 14994 search queries in 5486 sessions recorded between June 2003 and March 2005, or subsets thereof.

An important finding is that the average number of words used in a query is two. That average has not varied over time or with the introduction of new clients or across platforms. This is not surprising given the difficulty of data entry on many PDAs and confirms the need for aids to refining a search or organizing results.

One method for refining a search is to include search limits, such as Publication Type or Subset. Many limits are available using MD on Tap and are selected from the Profiles tab. It does, however, require an investment of time and effort to set up limits: the user must move to the Profile tab, select the various limits from the tab, move back to the Search tab and select the Use Profile option (see Figure 11). Users of our early clients rarely used limits. Starting with version 1.5, the client saved the last-used state of the Profile Tab and the search preferences on the Search tab, and restored these on startup, thus amortizing the initial time investment of Profile setup over multiple sessions. To examine the effect of this change, we compare the use of search limits for versions earlier than 1.5 and versions 1.5 or later, shown in Table 2. We see that although users remain disinclined to use search limits, they are more likely to do so if the settings persist. Because these settings are saved by the PDA client, there is no need for the user to log in or otherwise be identified to the intermediate server.

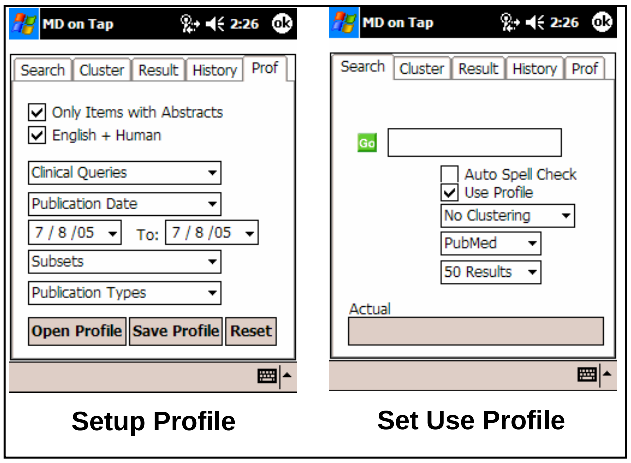


Figure 11. Setting up and using a Profile.

Table 2 – The use of search limits.

	Total number of search queries	Number of queries using search limits	Percent of queries using search limits
Versions earlier than 1.5	8831	843	9.5%
Versions 1.5 or later	6163	1000	16.2%

The characteristics of an “average” session are consistent over the several versions. In Table 3 we compare session averages for client versions earlier than 1.5 and versions 1.5 or later.

Table 3 – Session averages.

	Versions earlier than 1.5	**Versions 1.5 or later**
Number of sessions	3329	2157
Elapsed time	315.8 sec	315.6 sec
Number of transactions	7.40	7.49
Number of search queries	2.65	2.86
Number of citation requests	3.08	3.08
Number of save citations	.40	.45
Number of linkouts	.16	.29
Number of Related Article requests	.33	.47

Number of continued queries	.67	.34
Number of transactions between the first saved citation and the query for which it was a result	1.59	1.54
Time between the first saved citation and the query for which it was a result	61.0 sec	64.7 sec

Assuming our users are indeed clinicians, the approximately 5 ½ minute sessions are in keeping with published data[23,24] of the amount of time clinicians spend in search of an answer.

Our analysis software also parses the search terms of each query and uses the NLM-developed Metamap[25] algorithm to assign each term to one of six Semantic Groups: Disorders, Anatomy, Intervention, Drugs, Groups and Other. Counts of all possible combinations of these groups were generated for the 6163 search queries stored from clients with version 1.5 or higher. Figure 12 charts the top 15 combinations used.

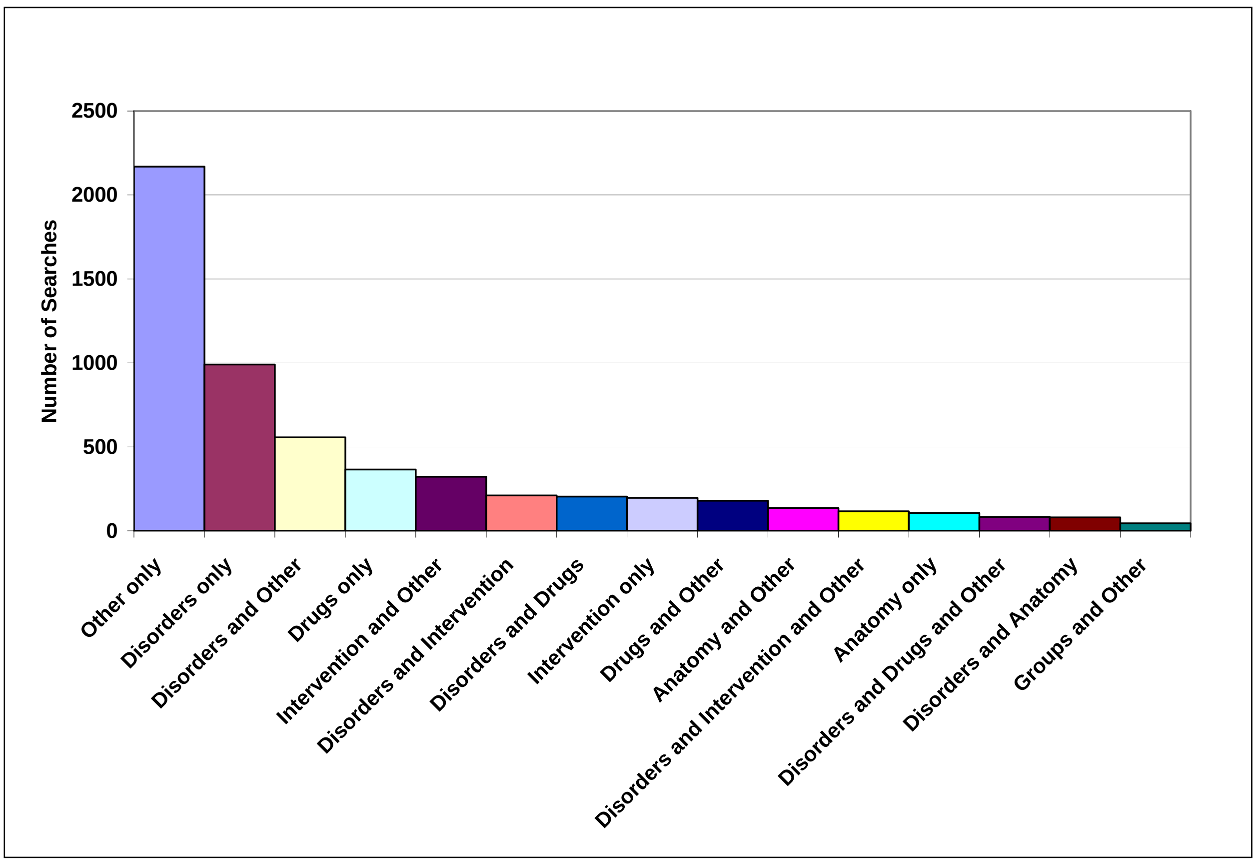


Figure 12. 15 Most-used Semantic Groups of 6163 Searches (5721 Searches).

The many terms categorized as "other" include misspellings, individuals' names and initials, Metamap errors and words that do not fall into one of these clinical categories.

We also observed that users occasionally misspell medical terms, either because of a graffito (graffiti error), "malarla" rather than "malaria" for example, or because the user does not know that correct spelling, "slerodermia" rather than "scleroderma", for example. When NCBI introduced the new E-spell e-utility in 2005, we tested it with 9546 unique queries in the server database that occurred between 6/17/04 and 3/17/05. E-spell returned suggestions for approximately 12% of those queries. We manually inspected 56 of these, comparing the user-entered query with the suggested alternative and noting the number of returned articles for each. We decided that the suggestions would have been helpful for about 82% of those queries, concluding that a suggested alternative would be helpful for about 10% of MD on Tap user queries. Although this may not seem to be a large percentage, the help could be significant considering the difficulty of data entry on many handheld computers. As always, implementing an added feature on the small screen was a challenge requiring decisions about what information was to be displayed. An Auto Spell Check option was added to our latest version, as described in Section 4.3.

5.1.5 Observational Study (point of service)

Early in 2005 we were fortunate to work with Dr. Victoria Sutton, a Health and Human Services Emerging Leader who spent a 10-week rotation with us. One of her tasks was to explore hurdles to the adoption of handheld computers by residents in a university teaching hospital. The MD on Tap project had been discussing our application with a local medical school that had already made considerable investment in wireless handheld technology. The school had installed a wireless network for the use of both laptop and handheld computers in the Hospital and clinic, purchased Pocket PC devices for the medical residents to use on site and acquired site licenses for several commercially-available medical resource programs for handhelds. The MD on Tap team worked with the school to develop a special client for the school that incorporated their choice of default settings and allowed the tracking of transactions from their site. However, months after the devices were distributed and the software made available, low use of the devices was reported by the school, and the MD on Tap application remained essentially unused. The school agreed to allow Dr. Sutton to explore the difficulties that a progressive, well-equipped medical institution had in realizing delivery of point-of-care information via wireless handheld computers. Of particular interest to this project was whether the application was useful in the clinical environment.

Dr. Sutton and the MD on Tap team arranged for an observational study of the existing system, its users, and the needs that were or were not being met by the available devices and software programs. Dr. Sutton accompanied a different medical team in post-call rounds every day for a week, carrying a Pocket PC equipped with MD on Tap and the online version of UpToDate[26], two of the medical resources available to the Residents. When appropriate, she searched these resources for answers to clinical questions that arose during rounds. She also spoke with team members and observed the environment, duties, and distribution of responsibilities within the team in order to better understand the needs of each team member and the constraints that a resource must meet in order to be valuable. She concluded that the impediments to widespread use of wireless PDAs were relatively basic and fixable: 1) The individual who both distributed the devices and set them up for wireless access was a busy chief resident, at the time on rotation at a different hospital and rarely available. This could be overcome by greater involvement of the

Information Technology services branch of the school. 2) There was no planned training for using the PDAs. Although the Residents did not desire extensive training, they did express a need for some basic training for both the device and the available programs. 3) There were logistical difficulties in gaining access to the network or the site-licensed software. The necessity to ensure reasonable network security measures, along with a lack of sufficient on-site IT support, resulted in a complicated scenario for students who wished to access the network or download applications. These difficulties could also be overcome with IT support.

On the positive side, Dr. Sutton found that the MD on Tap application was useful in addressing clinical questions that arose at the point of care. In fact, answers of varying utility were found for 17 out of 20 questions. One answer was found in the UpToDate database, and the rest were found in MEDLINE. Table 4 presents the summary of Dr. Sutton's observations. Questions are assigned to one of the four main clinical tasks that prompted clinicians to seek information. In addition, results are organized by roles of clinicians, Dr. Sutton's success in finding answers, time spent in search of an answer, and the answer's impact on the clinician's decision. Success in finding answers is shown as the ratio of answers accepted by clinicians to the total number of questions in the category. Time spent looking for an answer falls into one of the three intervals: 1) short – an answer was found within seconds of tapping the search icon; 2) medium – an answer was found in less than 10 minutes; 3) long – an answer was found after the round, and in one case almost a day later. The answer's impact on clinical decision is expressed as the ratio of answers that were directly applied in decision process, as for example selection of a drug dosage regimen, to the total number of accepted answers. Accepted answers that had no impact on clinician's decision were considered to be informative.

Table 4: Information delivery for hospital teams on rounds

questions from	supervisor					residents/students				
Clinical task	found	time			impact	found	time			impact
		short	med.	long			short	med.	long	
Therapy	4/6	2	2		4/4	6/6		2	2	2/6
Diagnosis	4/5		1	3	3/4					
Prognosis	1/1			1		1/1		1		1/1
Etiology/Harm						1/1			1	

Through Dr. Sutton's work we have a better understanding of the issues that an institution whose primary focus is medicine faces when it endeavors to incorporate technical components.

5.2 Technical Evaluation

5.2.1 Intermediate Server Performance

Between June 2003 and July 2005, the MD on Tap intermediate server responded to 30,065 search queries with an average response time of 1.404 seconds. During that time period, the server delivered 24,090 citations with an average response time of 0.539 seconds. These response times include time interacting with PubMed and/or with the MD on Tap database.

With the release in late September 2004 of version 1.5 for Pocket PCs, MD on Tap clients could request 50 (default), 40 or 20 results. Earlier clients supported requests for 20 or 10 results. We compare average response time for search queries for each number of results, for queries for which results were not clustered, for October 2004 to July 2005. Results are shown in Table 5. The response time increases approximately linearly with the number of results returned. Although the time savings is small, users with smartphones or low bandwidth networks may be happier with performance by selecting fewer results per page.

Table 5. Average response time as a function of number of returned results.

Number of returned results (no clusters)	Number of search queries	Average response time in seconds
50	9372	1.007
40	130	0.808
20	4597	0.606
10	50	0.335

Version 1.5 is also the first client to offer results clustered by both Subject or by EBM category. We compare average response time for search queries for either clustering option to search queries for no clustering, using 50 results as the baseline for all three. Results are shown in Table 6. Although both clustering options require additional server processing, less text is assembled for transmission than for no clusters, so the overall response time is reduced.

Table 6. Average response time as a function of returned results organization.

Returned results organization (50 results)	Number of search queries	Average response time in seconds
No clusters	7124	1.019
Subject clusters	1023	0.815
EBM clusters	742	0.696

The server program and database interface have been improved or upgraded over the course of the project. Of particular note are the implementation of database connection pooling, batch citation insertion and Tomcat upgrade which occurred during February and March, 2004, resulting in notably increased performance. Table 7 compares response time to search queries before February, 2004 and after March, 2004.

Table 7. Response time as a result of changes in server and Tomcat.

Date range (20 results, no clusters)	Number of search queries	Average response time in seconds
June 2003 – January 2004	1288	1.840
April 2004 – July 2005	11786	0.688

5.2.2 Search Engine Study

Essie is a probabilistic search engine developed by LHNCBC in support of the ClinicalTrials.gov website that ranks results by relevance.[27] Essie demonstrated one of the best performances in genomics TREC tasks for 2003.[28] In addition to its primary task of providing access to Clinical Trials database, Essie now also provides access to MEDLINE via an Applications Interface. We conducted a preliminary comparison of Essie and the PubMed search engine to determine if the alternative search engine would more efficiently identify MEDLINE citations of interest to a clinical user. Using five of the clinical questions obtained during the observational study described in section 5.1.5, we conducted an in-depth comparison of results from the two search engines. Evaluation was based on the ranking (i.e. position) of the clinically useful citations in the results list and the strength of the retrieved information, using the same search terms and limits for both searches. Essie performed as well or better than PubMed for all five clinical questions.[29] Essie was integrated into our latest version of MD on Tap as an option to PubMed. In addition to monitoring its use by our public users, we incorporate it in the explicit evaluation described in the section 6.4.

5.2.3 Performance on Smartphones

A potential collaborator (see Section 6.2) is using PDA/cell phones with Internet connection, i.e. smartphones, for the handheld computers used by medical students. Because data rates over cell phone networks are generally not as high as for WiFi, we are interested in understanding the performance of MD on Tap on cell phones. We were able to borrow two smartphones for a short time from a local Sprint representative. One phone has the Pocket PC operating system, and the other has the Palm operating system. In the absence of measurement tools for the phones themselves, we conducted a short manual evaluation of response time using a stopwatch. Overall response time includes PDA processing, PDA data transmission rates, cell network speeds, PubMed response time and MD on Tap server speed. We measured total time for set of 6 queries delivering 50 results each, and fetching 18 citations, using the same set and same steps for all devices. The two phones were compared to four WiFi PDAs, two with Pocket PC OS and two with Palm OS. To eliminate PubMed response time from the equation, all searches and citations were pre-stored in the MD on Tap database. To reduce the effect of the tester's cognitive and physical actions, the tap sequence for the search sequence was written down and rehearsed on each device. The searches were stored in the History of each device so that they would not have to be entered via graffiti or soft-keyboard. The results, shown in Table 8, compare total user time and MD on Tap system time for the two smartphones, two Palm PDAs and two PPC PDAs. Although the PPC phone takes about 50% more time that the equivalent WiFi PDAs, the overall response time is acceptable. The Palm phone takes almost 7 times as much time as the slower of the equivalent WiFi PDAs, making the response time unacceptable. Since both phones are using the Sprint cell system, we conclude that the cell phone data rates are not the issue, but rather some component in the interface between MD on Tap, the Palm OS, the data communications hardware in the Treo device and the Sprint proxy server. More research will be necessary to identify the source of the problem.

Table 8: Response time of two smartphones and four PDAs.

OS	Device	Total user time (min:sec:100ths sec)	Total server time (sec)	Server time for 6 queries (ms)	Server time for 18 citations (ms)
PPC	Sprint phone (PPC-6601)	2:22:90	1.120	132	988
PPC	iPaq 3850 (old; external WiFi)	1:36:67	1.842	196	1646
PPC	iPaq rx3115 (new; internal WiFi)	1:35;21	1.913	221	1692
Palm	Sprint phone (Treo 650)	16:56:34	3.005	486	2519
Palm	Sony Clie (old, external WiFi)	2:31:30	19.225	486	18739
Palm	Tungsten C (internal WiFi)	1:51:34	1.510	530	980

6. Current Work

6.1 Data Organization

MD on Tap currently provides three alternative views of search results presented in Figure 4. Our ultimate goal is to provide a compact single PDA screen overview of retrieved citations, and the possibility of immediate access to relevant documents. Principles of organization by content of the retrieved citations were researched prior to implementation of the categorical or Subject Area clustering. We experimented with two clustering approaches: Subject Area classification of documents using a constant set of pre-determined categories, and Dynamic Clustering using hierarchical clustering methods. Dynamic Clustering required generation of multi-document cluster labels. We considered two methods of cluster name generation: extraction of multi-document summaries, and selection of the most representative title from the set of citation titles in the cluster. Based on the results of our experiments[30] we selected clustering into pre-defined categories since the benefits provided by dynamic clustering in terms of document distribution and relatedness of documents in the cluster were outweighed by the speed of the subject area assignment that amounts to table look-up.

As mentioned in Section 4.2.2, clustering by strength of evidence is based on EBM recommendations as implemented in the strength of evidence taxonomy. MeSH terms and Publication Types are used to assign citations to the potential highest strength of evidence level as shown here:

Evidence Level 1:

- **Clinically Relevant Summary**
    - Meta-Analysis, Practice Guidelines, Consensus Development Conferences

- **Clinical Trials**
    - Controlled Clinical Trials, Randomized Controlled Trials, Multicenter Studies, Double-Blind Method

Evidence Level 2:

- **Clinical Evidence**
    - Studies: Case-Control, Cohort, Cross-Sectional, Cross-Over, Evaluation, Follow-up, Longitudinal, Retrospective, Twin, Validation, Case Reports
- **Review**

Evidence Level 3:

- **Other**
    - In Vitro, Animal and Animal Testing Alternatives studies, Journal Article, Editorial, Interview, Letter, Legal Case

6.2 Transaction Review for Medical Students

Led by faculty member Joshua Jacobs, MD, the John A Barns School of Medicine (JABSOM) in Manoa, Hawaii, has initiated the Mobile access Resource Project (MARP)[31] to improve electronic communication with and for medical students in the decentralized community settings and facilities in which they train. One goal of the MARP is to initiate and evaluate a mobile computing wireless system to support medical student access to health information, specifically NLM databases, at the point of learning. Dr. Jacobs has expressed interest in incorporating MD on Tap into the project. To further this potential collaboration, we developed special JABSOM clients that include a feature for students to set their UserID. This short string of characters becomes a tag sent with each transaction from the MD on Tap client. The MD on Tap intermediate server stores the UserID with each transaction, thus permitting special software to recover individual student transactions.

PubMed on Tap History for *student19*

Query text:	Request date:	Total articles:	Cluster:
zosyn dose pneumonia AND English[Lang] AND (human[MeSH Terms]+OR+hominidae[MeSH+Terms]) AND hasabstract	2005-03-04 09:22:41:	1	EBM

PMID: 12011536

Title: Comparative pharmacokinetic and pharmacodynamic profile of piperacillin/tazobactam 3.375G Q4H and 4.5G Q6H.
Author List: Mattoes HM , Capitano B , Kim MK , Xuan D , Quintiliani R , Nightingale CH , Nicolau DP
Affiliation: Department of Pharmacy Research, Hartford Hospital, Hartford, Conn., USA.
Journal: Chemotherapy. 2002 May;48(2):59-63.
Abstract: When piperacillin/tazobactam has been used to treat hospitalized patients with serious infections, including nosocomial pneumonia caused by Pseudomonas aeruginosa, it has usually been dosed at 3.375 g q4h to provide serum concentrations above commonly encountered organisms' MICs (T > MIC) for at least 40-50% of the dosing interval. Pharmacodynamic principles suggest that a similar efficacy can be realized with extended dosing intervals when a larger dose (e.g. 4.5 g q6h) is administered, which was the objective of this study. Twelve healthy volunteers, 29.4 +/- 8.9 years of age, were enrolled in this multiple-dose, open-labeled, randomized, two-period crossover study. Blood samples were collected after the third dose and concentrations of piperacillin/tazobactam were determined with a validated HPLC method. Pharmacokinetic profiles were determined by noncompartment analysis. T > MIC of piperacillin was calculated for a range of MIC values. Piperacillin/tazobactam was well tolerated in 11 subjects who completed both regimens. The C(max), T(1/2), K, and AUC of P were significantly different according to a paired t test (p < 0.05) between two study regimens. Significant differences (p < 0.05) in tazobactam regimens were noted for C(max), and AUC. The piperacillin/tazobactam regimen of 4.5 g q6h achieved a 44% T > MIC for MIC values of < or = 16 microg/ml, while the 3.375-gram q4h regimen achieved 42% T > MIC, for MIC values of < or = 32 microg/ml. Dosage regimens for treating serious infections can be extended safely and effectively to 4.5 g q6h and obtain at least 40-50% T > MIC in the coverage of pathogens implicated with serious infections, including P. aeruginosa.
Subject: Drug Therapy
Link out: http://content.karger.com/produktedb/produkte.asp?typ=fulltext&file=che48059
EBM Cluster: Clinical Trials

Figure 13. JABSOM student MD on Tap transactions review.

To complement the special clients, we developed a browser-based tool to let students review their MD on Tap searches when they return to desktop computers. Figure 13 is a short example of what the student would see at the desktop computer after an initial page in which they enter their UserID and select the desired time frame to review. The student sees details of the transactions in the order in which they were executed. Search details include limits, display options and the total number of results. Citation details include PubMed ID (PMID), Subject and EBM categories of the citation and, if available, the URL for the full text of the article. The student may click on the search text to execute the same search using the native PubMed browser interface, click on the PMID to view the citation using the PubMed browser interface, or click on the full text URL to view the given publisher or NLM PubMed Central website. A similar tool is available for JABSOM faculty in which transactions are grouped by student UserID.

The ability to recognize JABSOM-generated transactions allows us to compare the use of MEDLINE and MD on Tap by medical students to our general population of users. We intend to share such comparisons with Dr. Jacobs. Although this system was developed specifically for JABSOM, it could be adapted for other institutions with modest development effort.

6.3 On-site Teaching Hospital Evaluation

Through analysis of the de-identified transactions received from clients we have explored and identified several aspects of aggregate user behavior regarding searching MEDLINE with a handheld computer. However, our ability to relate the query terms and retrieved citations to the clinical scenario being addressed is limited. With careful manual examination of recorded transactions we can occasionally infer the clinical question being asked, but with insufficient confidence to determine if the question was answered by the citations retrieved. To better understand the role of MEDLINE in answering such questions and the ability of the MD on Tap application to be an effective interface to MEDLINE in clinical settings, we require a structured, on-site evaluation of MD on Tap in a clinical environment.

Encouraged by Dr. Sutton’s success in answering clinical questions while accompanying medical teams on rounds, we applied for and won an NIH Evaluation Grant to contract for a more extensive study of that nature. Our intent is to observe and record the use of the MD on Tap system in real clinical scenarios, thus gaining an understanding of the features of the MD on Tap system design that are most useful for quickly finding relevant, high-quality journal article citations. The study will also evaluate MEDLINE’s role in this environment as a tool for the practice of Evidence Based Medicine. With the NIH Evaluation Grant funds, we are contracting a clinician and institution for data generation by the clinician while accompanying a Medical team on rounds in a teaching hospital for 8 weeks. For each question raised at the point-of-care the clinician will use MD on Tap to search MEDLINE for relevant citations and save those citations judged to be useful in answering the question. The clinician will also log the clinical scenario for each question and the EBM category of the question and submit these logs electronically to the MD on Tap team. We have developed special software to synchronize the transactions to the clinician’s log. Dr. Mohammad Al-Ubaydli of NCBI, an experienced MD, will corroborate the relevance of the selected citations to the logged clinical scenario and, if necessary, clarify ambiguous associations. Analysis of the logs and the transactions will permit evaluation of the ability of MEDLINE to assist clinicians as well as ability of MD on Tap to be an effective interface to MEDLINE.

We anticipate that the data generation phase of the evaluation will begin in October, 2005.

6.4 Outcomes Identification

Dr. Jacobs' request for desktop tools that augment MD on Tap with review capabilities, clinician's willingness to accept and act upon Dr. Sutton's delayed answers in non-critical situations, and lessons learned with respect to "More Information" display lead us to believe that automatically extracted summaries of abstracts will be a welcome extension to MD on Tap and need to be researched. The importance of patient oriented summaries in clinical decision support was recognized in the early 1990s when Cochrane Collaboration was set up, and techniques for efficiently obtaining Patient-Oriented Evidence that Matters were developed.[32] We focus on automatic patient outcome identification as the first step in the generation of these summaries.

We evaluated several approaches to outcome identification in collaboration with Barbara Few, a registered nurse with over 20 years of clinical experience and Master of Science degrees in nursing and information, who undertook investigation of outcome identification methods as her NLM associate fellowship project. The first researched venues were the amount of text, the availability of MEDLINE indexing information, and the extent of document understanding necessary to identify articles containing clinically relevant and valid information. A group of four annotators (Barbara Few, Susan Hauser, Dina Demner-Fushman, and Malinda Peoples, RN) had only moderate agreement in a macro-level approach, where citations as a whole were identified as 'just-in-time', clinical, or non-clinical. A much better agreement was achieved in a micro-level approach, where each sentence in the citation was annotated as belonging to one of the fields of the EBM framework for appraisal of medical literature. This research resulted in development of an annotation scheme presented in Table 9; a collection of Medline citations annotated at the sentence level (see collection description in Table 10 and inter-annotator agreement in Table 11), and identification of essential textual, structural and meta-information features for automatic extraction of outcome sentences.

Table 9: Scheme for annotation of clinically relevant elements in MEDLINE citations.

Tag	Definition
Background	Material that informs and may place the current study in perspective, e.g., work that preceded the current; information about disease prevalence, etc.
Population	The group of individual persons, objects, or items comprising the study's sample, or from which the sample was taken for statistical measurement
Intervention	The act of interfering with a condition to modify it or with a process to change its course (includes prevention)
Statistics	Data collected about the results of the intervention demonstrating its effect
Outcome	The sentence(s) that best summarizes the consequences of an intervention
Supposition	An assumption or conclusion that goes beyond the evidence presented in an abstract
Other	Any sentence not falling into one of the other categories and presumed to provide little help with clinical decision making.

Table 10: Five sets of MEDLINE citations that form the test collection.

Set	Search topic	annotators	citations	with outcome
1	rheumatoid arthritis, migraine, breast cancer	RN1	275	275
2	exercise-induced asthma, renal hypertension, pulmonary tuberculosis	RN1, medical student	123	123
3	immunization	RN1, RN2, MD, Ph.D.	50	33
4	diabetes	RN1, RN2, MD, Ph.D.	50	33
5	Treatment Outcome[mh]	MD, Ph.D.	135	128
total			633	592

Table 11: Inter – annotator agreement (Cohen's kappa) in outcome identification.

Set	annotators	annotation	all	clinicians	Best pair wise
2	RN1, MS	outcome	0.42	0.42	0.42
3	RN1,RN2,Ph.D.,MD	full	0.65	0.63	0.75
4	RN1,RN2,Ph.D.,MD	full	0.63	0.77	0.84
5	Ph.D., MD	outcome	0.75	-	0.75

The created collection and features were subsequently used in our approach to automatic outcome identification as a text classification problem, in which we evaluate probability of each sentence in the text of MEDLINE citation belong to an outcome statement. As a result of preliminary experiments in which no single classifier demonstrated acceptable performance, we implemented stacking -- an ensemble of classifiers known to perform well when classifiers are disparate in nature. Figure 14 presents the base classifiers, input to the base classifiers, and output of the stacking meta-classifier.

We evaluate automatic outcome extraction using two different ways to combine base classifiers, ad hoc and stacking, for each of the four main physician's tasks: etiology, diagnosis, therapy, and prognosis in an intrinsic evaluation. The results of outcome extraction are shown in Table 8, where numbers 1 through 3 indicate the sentence cutoffs in selecting sentences with top scores assigned by outcome classifiers. In the evaluation, the prediction of the outcome extractor was considered correct if the sentences it returned intersected with sentences judged as outcomes by our annotators. We select this lenient evaluation because of the importance of pointing the physician in the right direction, even if the results are only partially relevant.

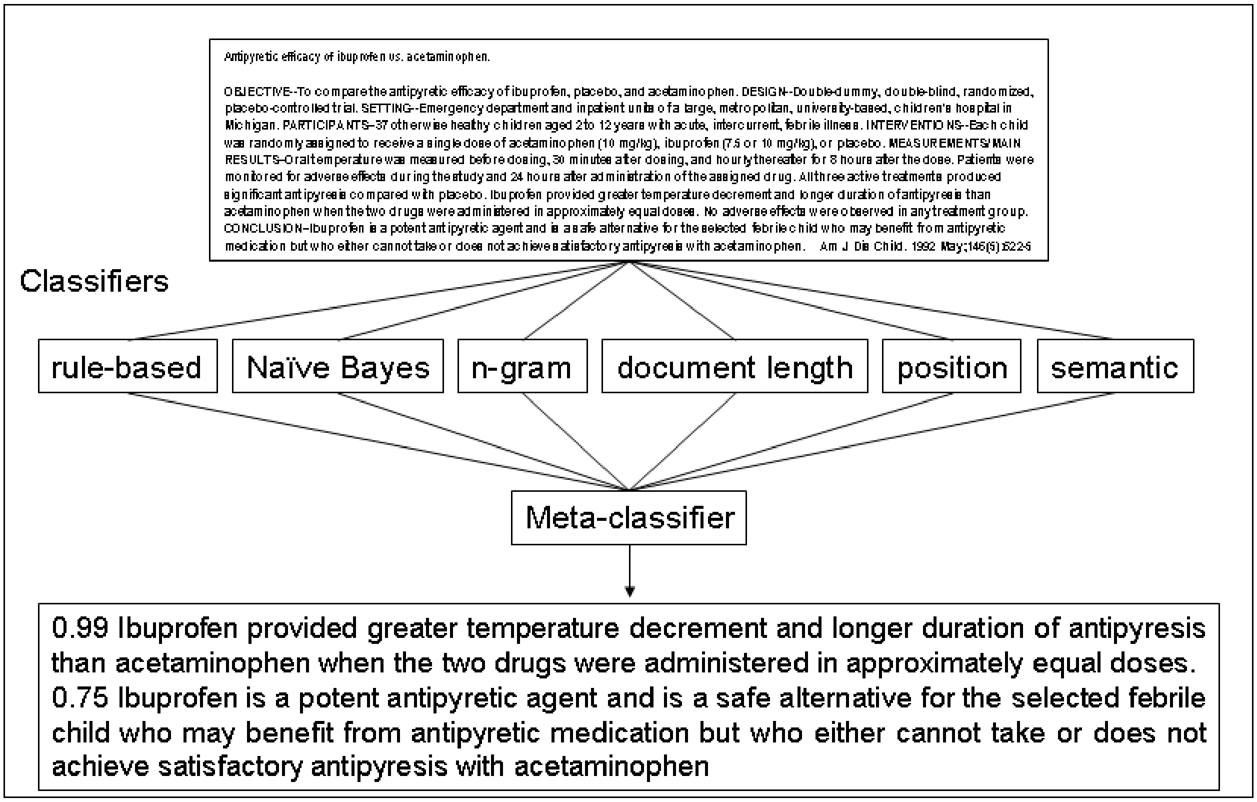


Figure 14. Ensemble of outcome classifiers.

As can be seen in Table 12 the ensemble of classifiers achieves acceptable performance when three top ranking sentences are selected as an outcome statement.

Table 12: Percent of correctly identified outcome statements at three cutoff levels for each major clinical task.

Extractor	**Baseline**			**Meta-classifier**					
				rule-based			**stacking**		
amount / **Task**	1	2	3	1	2	3	1	2	3
Etiology	34.5%	63.6%	78.2%	47.4%	68.4%	82.5%	52.6%	73.7%	87.7%
Diagnosis	44.4%	72.2%	75.0%	56.8%	70.3%	78.4%	67.6%	78.4%	89.2%
Therapy	38.6%	74.0%	75.0%	49.0%	75.0%	95.0%	51.0%	77.0%	92.8%
Prognosis	49.5%	73.0%	84.7%	63.1%	75.7%	87.4%	60.4%	79.3%	89.2%

The ultimate measure of success of outcome extraction is its performance in a real-life task. For a preliminary evaluation in a real-life information retrieval task we carried out automatic outcome-based ranking of 1312 MEDLINE citations. The citations were retrieved using the sensitivity oriented therapy clinical query available in PubMed to answer clinical inquiries for five disorders. A family practitioner provided relevance judgments for 40 citations retrieved for each of the disorders as described in Sneiderman.[33] We used the standard NIST evaluation procedures[34] to evaluate the performance of the outcome-based ranking of citations. Although using mean average precision (map) – a measure frequently used in official NIST evaluations -

we obtained a three-fold improvement (map = 0.4131) over the presentation order of the citations in PubMed retrieval results (map = 0.1425), we consider the number of relevant documents displayed at the top of a ranked list to be a more meaningful measure for point-of-service information delivery. Number of relevant documents in the first ten of the PubMed retrieval results and after ranking is shown in Table 13 along with the total number of the retrieved citations.

Table 13: Number of relevant documents in the first 10 of the PubMed retrieval results (PM) and after the EBM model-based re-ranking (EBM).

	Back pain		**Obesity**		**Osteoporosis**		**Panic disorder**		**Warts**	
Ranking	PM	EBM	PM	EBM	PM	EBM	PM	EBM	PM	EBM
Relevant in first 10	3	10	0	7	1	9	5	9	0	9
Total retrieved	246		181		513		268		104	

7. Further Work

Practically every aspect of our research so far merits an in-depth investigation. For example, clinicians might benefit from expansion of resources accessible via MD on Tap to evidence-based clinical practice guidelines from the Health Services Technology/Assessment Texts (HSTAT).[35] The titles of the Evidence Report Summaries and their Findings chapters might be provided in a manner similar to the display of MEDLINE citations. However, providing links to PDA versions of the documents[36] for further investigation of guidelines poses a question of application integration. Furthermore, the HSTAT summaries could be further compressed and individually tailored using the original search request.

We will seek to extend our evaluation work with teaching hospital (Section 6.3) to include longer evaluations with additional variables, such as student questions vs. attending questions, and a thorough analysis of the existing and future capabilities of MD on Tap system. We hope to also extend our relationship with JABSOM to include structured evaluations. In this vein, we also hope to find or develop diagnostic and/or performance measurement tools for the Palm and Pocket PC operating system to assess response time and other performance factors from the client perspective.

The task of providing patient outcome oriented summaries of MEDLINE search results is an immediate goal that will be accomplished using the Outcome and other EBM framework elements as presented in the next section.

7.1 Integrating Outcomes

Integration of the existing Outcome extractor is the first step towards providing patient outcome oriented summaries of search results. The summaries, consisting of the title of the abstract and three highest ranking outcome sentences will be generated using Clinical Question answering system prototype developed in cooperation with Dr. Jimmy Lin, assistant professor, University of Maryland, College Park and NLM visiting scholar. Initially the summaries will be provided and critically evaluated within the Transaction Review for Medical Students interface described in Section 6. Figure 15 presents an overview of the system that incorporates domain knowledge encoded in UMLS into a standard architecture of modern question answering systems. The asynchronous answer generation process will be triggered by a single request or a session completed by a user who has opted to use this service. The query and the documents will be processed using MetaMap to identify elements of the EBM well-built clinical question and literature appraisal frameworks. These elements are identified and extracted by the Knowledge Extractor that implements Problem, Population and Intervention Extractors in addition to the Outcome Extractor.[37] Even our initial simple approach, in which answer generation amounts to extraction of outcome statements, poses interesting questions that have to be resolved: 1) should every request trigger answer generation, or only those in which the user showed some interest, e.g. looked for related articles, saved a citation, retrieved more than the initial set? 2) how many documents should be processed – only those retrieved by the user, top 100, or everything available?

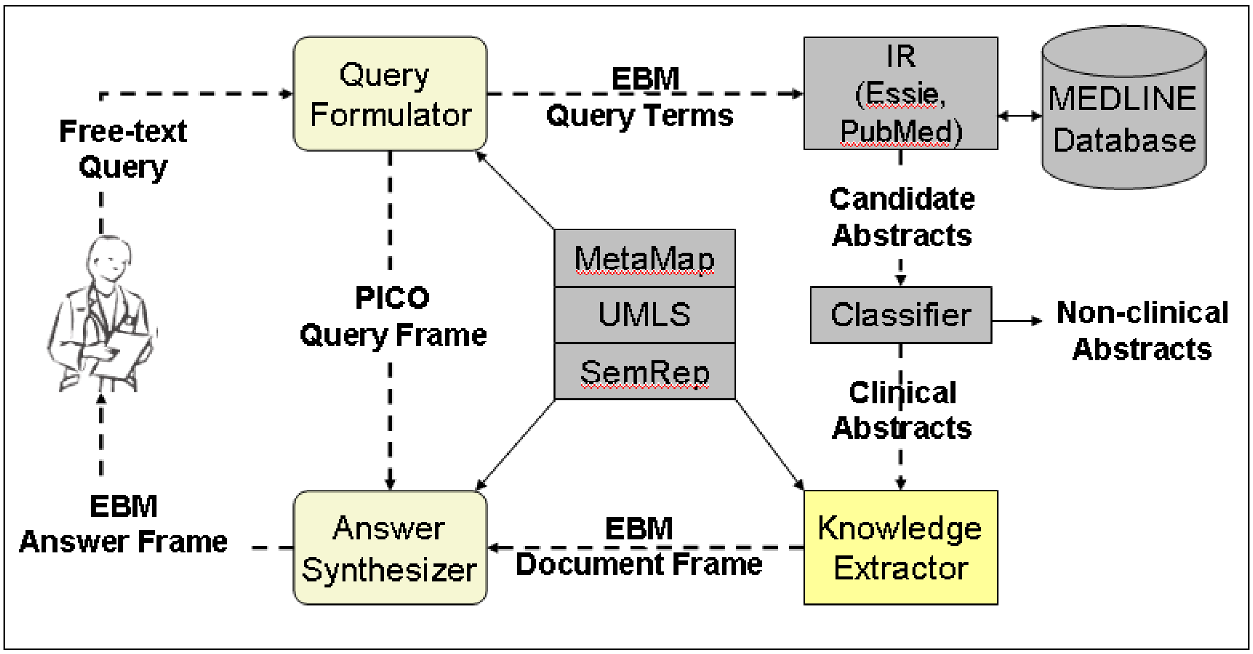


Figure 15. Clinical Question Answering system.

Further development of the Transaction Review module will involve generation of personalized summaries, in which the original query will guide the answer generation and the organization of results.

7.2 Results Summaries/Digests

The idea of providing individually tailored summaries of search results was explored in the PERSIVAL project where a patient profile consisting of a term-value pair from the patient's chart served as a guide in interactive query formulation and summarization of the results.[38] Our approach extends the PERSIVAL methodology in three important directions: the system does not have direct access to patients' records; initial summary generation is a value added to the users' original interaction with the system without an additional user's effort; summaries will be generated using domain model and semantic rather than lexical similarity of documents and queries, which allows for identification of the EBM framework elements in MEDLINE citations independent of the query. Figure 16 presents an ideal situation when the clinical task that generated the question is known (Therapy) and all elements of a well formed clinical question are present in the query. In this situation generation of the summary amounts to semantic unification of the query and the document frames. The first step in this unification is matching on the clinical problem. If the main problem, i.e. the focus of a MEDLINE citation is not identical or synonymous to the problem in the request, the citation will be excluded from the summarization process, and will be categorized under the identified problem. Citations that pass this initial filter are than processed through the intervention filter. Citations identified to focus on the interventions present in the request are preferred, but other citations are not excluded from further processing. For citations that focus on the same interventions processing will involve integration with SemRep[39, 40] processing that will provide a deep understanding of the patient outcome. For example, outcomes from two citations in Figure 16 have identical semantic representation and can therefore be grouped. Final representation of the group is selected based on the strength of evidence so that the user views key points and a list of sources for each as shown in Figure 17.

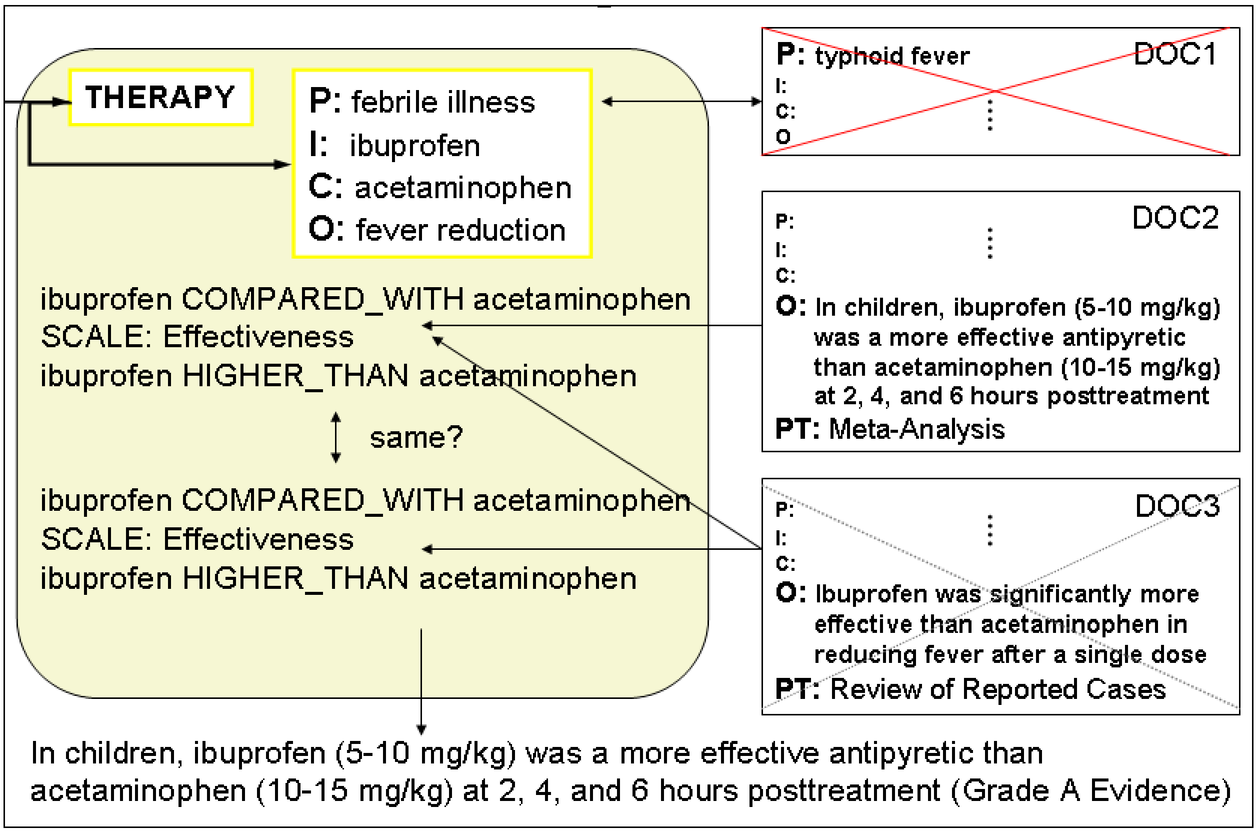
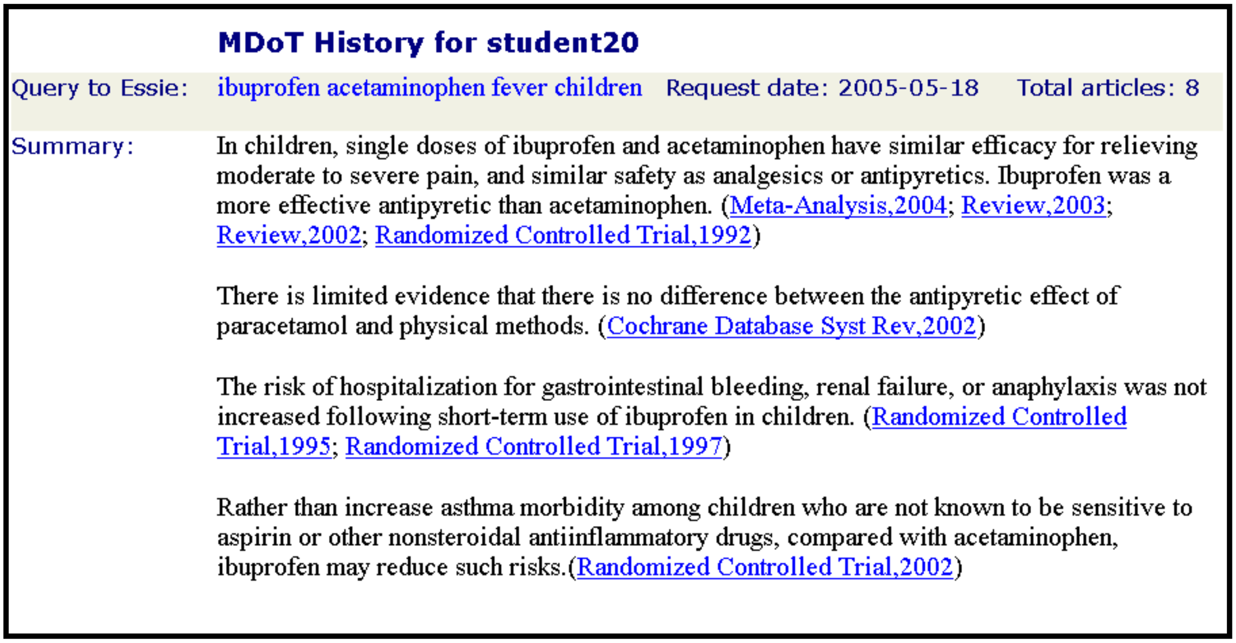


Figure 16. Digest Generation.



MDoT History for student20

Query to Essie: ibuprofen acetaminophen fever children Request date: 2005-05-18 Total articles: 8

Summary: In children, single doses of ibuprofen and acetaminophen have similar efficacy for relieving moderate to severe pain, and similar safety as analgesics or antipyretics. Ibuprofen was a more effective antipyretic than acetaminophen. (Meta-Analysis,2004; Review,2003; Review,2002; Randomized Controlled Trial,1992)

There is limited evidence that there is no difference between the antipyretic effect of paracetamol and physical methods. (Cochrane Database Syst Rev,2002)

The risk of hospitalization for gastrointestinal bleeding, renal failure, or anaphylaxis was not increased following short-term use of ibuprofen in children. (Randomized Controlled Trial,1995; Randomized Controlled Trial,1997)

Rather than increase asthma morbidity among children who are not known to be sensitive to aspirin or other nonsteroidal antiinflammatory drugs, compared with acetaminophen, ibuprofen may reduce such risks.(Randomized Controlled Trial,2002)

Figure 17. Mock-up of a digest.

Analysis of our user transactions shows that most probably the query frames will be instantiated only partially, i.e. only two words per query on average. In such cases semantic clustering by elements of the EBM framework, e.g. Problem, will be provided. Once organization principles are approved by users testing in a desktop web environment, ways to present summaries within MDoT will be researched.

7.3 Client Development

All current and future discoveries depend on our ability to attract and keep mobile healthcare providers as MD on Tap users, and to obtain feedback from these users. We think there are two approaches that we could conceivably take toward this goal. One is to develop clients for the increasing number of platforms available to handheld computer customers. The other is to nurture relationships with potential collaborators and develop special features for their environments.

7.3.1 Multi-platform

Although Palm and Pocket PC devices continue to be popular among clinicians, their dominance in this arena is being challenged by other platforms. Blackberries from Research in Motion (RIM) have become standard handheld devices for administrators and technicians, primarily because of their email capabilities and their attention to security. As they add more functionality, they are likely to become widely used among clinicians as well. The Blackberry operating system is based on JAVA, and RIM offers an integrated development environment for building Java™ 2 Micro Edition (J2ME™) applications for Blackberry devices. Symbian OS, the basis of many smartphones, is also Java-based. A free Java Virtual Machine (JVM) is available for Palm OS devices, and a non-free JVM is available for Pocket PC devices. In August 2004, we explored several Java-like development environments for handheld computers and concluded that there was not yet a solution for multi-platform client development that would efficiently support all popular platforms.[41,42]

7.3.2 Special Environments

Dr. Jacobs, our potential collaborator in Hawaii, is using Palm and Pocket PC smartphones in his project. Our client could be developed further to respond to more of the physical controls found on phones and not on traditional PDAs, such as up, down, left, right and select buttons. Adding these controls would make operation easier for Dr. Jacobs' students, but would require considerable development effort.

Likewise, the on-site teaching hospital evaluation will certainly generate ideas for an enhanced client specific for that environment that could engender an extended collaboration with that institution.

The Medical School at Makerere University in Kampala, Uganda is another opportunity to explore information delivery to an environment with special circumstances. The Medical school is expanding its problem-based learning curriculum by adding wireless network components and wireless PDAs to the University resources. We have recently introduced their technical and library staff to MD on Tap. The librarians are downloading citations from NLM via MD on Tap using several Pocket PC PDAs. The Faculty of Medicine is partnering with NLM on several initiatives,[43] and their dean, Prof Nelson Sewankambo, is participating in NLM's Long Range Plan meetings. The University's connection to the Internet and thus to NLM is relatively low speed which is not expected to be a barrier since MD on Tap does not require high bandwidth to perform well. We intend to observe the use of our system in this environment, evaluate its performance, and note special requirements that suggest further design opportunities.

8. Summary

The project pursues two goals stated in NLM's Long Range Plan 2000-2005:

- Goal 1: Organize health-related information and provide access to it.
    - Access to information is provided via the MD on Tap PDA application.
    - Organization of information is initially researched outside of the PDA interface, and then implemented based on the results of the studies.
- Goal 2: Encourage use of high quality information by health professionals and the public.
    - This goal motivates our active pursuit of cooperation with clinicians, our study of hurdles in using information at the point of service, and our exploration of effective techniques for presenting information on a small screen over low bandwidth networks.

We built a testbed system based on a client-plus-intermediate-server design and developed freely available clients for the two PDA operating systems most widely used by clinicians. The testbed system design has worked well for our research purposes. The servlet has proven to be nimble in response to changes in PubMed or database design, and sufficiently powerful to accomplish data processing with little to no effect on overall response time. The lean client exhibits fast performance and offers opportunities for personalization without system login. Our service supports users from all over the world (see Figure 18), many who elect to register for updates and announcements.

Through our usability study, observational studies, user feedback conduits and transaction analysis we have discovered several aspects of typical user search behavior and general design principles for delivering health information to wireless handheld computers. Through collaborative evaluations with medical institutions we anticipate an even better understanding of methods to meet the specific needs of mobile clinicians. The growing user base, interactions with our users, and our observational studies give us confidence that continuing development of MD on Tap will further support the goals of NLM's long range plan.

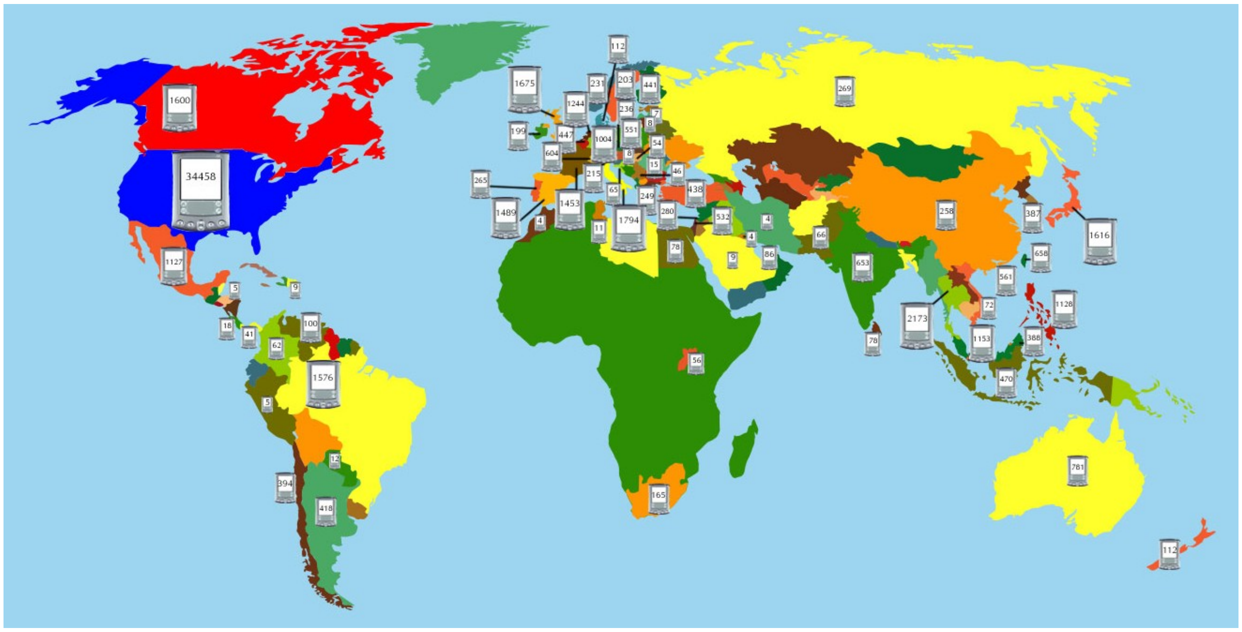


Figure 18. MD on Tap transactions from 69 countries throughout the world, 2003-06-18 to 2005-08-30.

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The MD on Tap team thanks the many individuals who have contributed to the project:

- Karen Steely for design and implementation of the MD on Tap website, help with usability studies and initial development of the transaction tracking software.
- Kathi Canese and the E-Utilities team.
- Susanne Humphrey for many insights with respect to controlled vocabularies.
- Alan Aronson and Thomas Rindflesch for many discussions of the semantic knowledge representation and its integration with MD on Tap.
- Nicholas Ide and Russell Loan who developed and continue to support the clinical search engine.
- Jing Cheng for ongoing website support.
- Mohammad Al-Ubaydli for contributions to the on-site teaching hospital evaluation.
- Will Rogers and Guy Divita for their help with knowledge representation tools.
- Michael Chung for help with graphical design decisions.
- Julia Royall for introducing us to Makerere University, Uganda.

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APPENDIX A: Curriculum Vitae

Dina Demner-Fushman
Glenn Ford
Mike Gill
Susan Hauser
Tri Quang Nguyen
George Thoma

Curriculum Vitae

Dina Demner-Fushman
NLM fellow, Communications Engineering Branch, LHNCBC, NLM, NIH

Education and Training:

S.V. Kurashov State Medical Institute, Kazan, USSR	M.D.	1980	Medicine, Dentistry
Semashko Medical and Stomatological Institute, Moscow, USSR	Ph.D.	1989	Medicine, Immunology
Hunter College, CUNY, New York, NY	B.A.	2000	Computer Science
University of Maryland, College Park, MD	M.S.	2003	Computer Science

Research and Professional Experience:

2004- Medical Informatics Fellowship, Lister Hill National Center for Biomedical Communications, NLM

Responsibilities:

- Server software developer for MD on Tap project
- Research and development of retrieval results organization
- Research and development of semantic knowledge utilization in information extraction
- Research and development of clinical question answering principles and software

2002-2004	Information Technology Specialist, Lister Hill National Center for Biomedical Communications, NLM
2000-	Graduate research assistant Computational Linguistics & Information Processing Lab, UMCP
2000	inducted into Phi Beta Kappa
2000	Honorable mention in the CRA's Outstanding Undergraduate Award
2000	Who's Who among students in American Universities & Colleges
2000	Bachelor of Arts, Summa cum Laude, in Computer Science, City University of New York
1999-2000	Research assistant, Research Foundation of the City University of New York
1998-1999	College assistants OICIT, Hunter College, City University of New York
1994-1997	Dental Assistant/ Office Manager, New York, NY
1991-1994	Orthodontist, Frankfurt/M., Germany
1989-1991	Assistant professor, S.V. Kurashov State Medical Institute of Kazan, USSR
1985-1989	Doctoral Program, Semashko Medical and Stomatological Institute, Moscow, USSR
1980-1985	Orthodontist, Kazan, USSR
1980	Doctor of medicine, Summa cum Laude, S.V. Kurashov State Medical Institute of Kazan

Publications (*peer reviewed*)**:**

Demner-Fushman D, Few B, Hauser SE, Thoma GR. Automatically identifying health outcomes in MEDLINE records. JAMIA 2006 (to appear).

Demner-Fushman D, Hauser SE, Thoma GR. The Role of Title, Metadata and Abstract in Identifying Clinically Relevant Journal Articles. AMIA 2005 (to appear)

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Humphrey SM, Rogers WJ, Kilicoglu H, Demner-Fushman D, Rindflesch TC. Word Sense Disambiguation by Selecting the Best Semantic Type Based on Journal Descriptor Indexing: Preliminary Experiment. JASIST, 2005:56(13) (to appear)

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Curriculum Vitae

Glenn Ford
Senior Software Engineer

Education and Training:

Montgomery College, Germantown MD	A.A.	1989	Computer Science
University of Maryland, Baltimore MD	B.S.	1991	Computer Science

Research and Professional Experience:

1996 – Present Communications Engineering Branch, LHNCBC, NLM

- Lead software developer for the PubMed On Tap research project. PubMed on Tap is an application for PDAs that facilitates Internet access to NLM's MEDLINE database using PubMed ultilies. The client is written in C++ using CodeWarrior 9.0 and the servlet is in Java with Tomcat.

- Lead developer for a web-mediates ground truth database for biomedical journals. Developed a set of ground gruth data and tools for the analysis of information extraction from scanned articles. Algorithms that researchers can explore are for page segmentation, zone identification, OCR character features, and data manipulation. Website is at http://marg.nlm.nih.gov.
- Conducts research and development for an automated data entry system for MEDLINE medical journals. The system, MARS (Medical Article Records System), automatically detects and extracts citation information from biomedical journal articles.

- Designed and developed WILL (Workstation for Interlibrary Loan). WILL encapsulated all the technologies necessary to capture, recognize and deliver medical articles via the Internet, fax, or print. WILL was used in production at the National Institutes of Health Library.

1997 Consultant, Panda Publishing Inc. : West Group Publishing

- For West Group Publishing, Mr. Ford was lead design engineer in charge of developing the Estate Planning System (EPS) for Windows. The EPS software, completed in December 1998, handles Estate Tax Forms 706, 709 and 1041, including all schedules and worksheets. The system uses an image rendering tool developed internally to allow on-screen WYSIWYG form data entry.

1997 Consultant, Panda Publishing Inc. :
Naples Florida Chamber of Commerce

- For the Chamber of Commerce in Naples, Florida Mr. Ford developed a Recreational Travel CD-ROM system to highlight the attractions in Naples, Florida. Designed and developed a system that uses over 2,000 images taken, developed and processed by Panda Publishing, using a full-text engine and hyperlink.

1994 – 1995 Consultant, Corporate Software : Hearst Business

- Designed and developed a car dealer inventory system (Black Book), for Hearst Business. As project manager for Hearst, Mr. Ford was responsible for two other developers and served as the project lead on all of Hearst's software systems.

Publications

- Alexander GL, Hauser SE, Steely K, Ford G, Demner-Fushman D. A Usability Study of the PubMed on Tap User Interface for PDAs Proceedings of 11th World Congress on Medical Informatics (MEDINFO) 2004 Imaging Informatics. September 7-11 2004; San Francisco, CA, USA. 1411-15
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- Thoma GR, Hauser SE, Ford G. Automating document delivery: a case study Proc. the 12th Annual Computers in Libraries. Arlington, VA. Published by Information Today, Inc. March 10-12, 1997; 137-9.

Curriculum Vitae

Michael Gill
Electronics Engineer, Communications Engineering Branch, LHNCBC, NLM, NIH

Education, Training, Certifications, Professional:

Learning Tree, Reston VA	2004 Network Security Certified Professional
Learning Tree, Reston VA	2003 Enterprise and Web Security Certified Professional
Learning Tree, Reston VA	2002 TCP/IP Certified Professional
IEEE	1999 Senior Member, IEEE
University of Maryland, College Park, MD B.S.	1982 Electrical Engineering

Research and Professional Experience:

1986-Present Communications Engineering Branch, LHNCBC, NLM

-*Medline Database on Tap (MDOT):* Technical team member, contributing to this investigation into understanding application design issues for portable computing systems. MDOT gives Medline access at the point of care.

-*Disk-based Lossless Digital Video Preservation:* Working with Dr. Glenn Pearson investigating issues with file format selection for biomedical video archiving.

-*NLM Internet2 Connectivity Team:* Technical team member involved in all phases of ordering, developing, implementing, testing NLM's advanced R&D network connectivity to the Internet2 backbone (Abilene), the local Gigapop (MAX), representing NLM at the Joint (Interagency) Engineering Team monthly coordination meetings, technical co-project officer for various (past) SII awards in OHPCC. Advising NLM on advanced telecommunication services involving Internet1 and Internet2 connectiivty.

-*Advanced Communication Technology Analysis:* Provides critical analysis of new and emerging communications technologies such as DWDM, POS, ATM, and fiber-optic based switching and advising on ramifications to senior management.

1982-1986 Telecommunications Engineer, MCI Communications Corp.

Publications:

Pearson G, Gill M. An Evaluation of Motion JPEG 2000 for Video Archiving Proc. Archiving 2005, April 26-29, Washington, D.C., IS & T (www.imaging.org), pp. 237-243.

Nishinaga N, Tatsumi H, Gill M, Akashib A, Nogawa H, Reategui I. Trans-Pacific Demonstration of Visible Human (TPD-VH). Space Communications 17:4, March 2002

Fan Y, Kyung H, Gill M, Huang HK. Some connectivity and security issues of NGI in medical imaging applications. Journal of High Speed Networks IOS Press, Vol. 9 (2000) pp. 3-13.

Gill MJ, Long RL, Ostchega Y, Goh G, Neve L, Thoma GR. Advanced Communications Technology for Biomedical Data Dissemination via Client/Server Architectures using Asynchronous Transfer Mode. In: Proceedings of 1997 Joint Meeting of the Public Health Conference on Records and Statistics and the

Data Users Conference: Partnerships, Technologies & Communities: Evolving Roles for Health Data, CD-ROM No. 1, Washington, DC July 28-31,1997.

Long LR, Gill MJ, Thoma G. High speed satellite access to biomedical text/image databases. Forum on Research and Technology Advances in Digital Libraries, Washington, DC: The Library of Congress, May 13-15; 1996.

Talks/Presentations:

Presentation, *"Next Generation Internet/Internet2 at the National Library of Medicine"*, For Native American Youth Initiative Participants, NLM, June 19, 2001

Presentation, *"High Speed Networks"*, National Library of Medicine, For Dr. Shigekoto Kaihara, MD, Director, Medical Information System Development Center February 9, 2001.

Invited Talk, *"Next Generation Internet/Internet2 Infrastructure the National Library of Medicine"*, Internet2 Day, the Bush Presidential Conference Center, Texas A&M University, College Station Texas February 9, 2001.

Invited Presentation, Gill, M. Reijs, V. *"Transatlantic Packet Loss NLM<=>HEAnet"*, Internet2 General Members Meeting Atlanta, Georgia, October 31, 2000.

Invited Presentation, Gill, M, Tatsumi, H. *"NLM- Sapporo Medical University Visible Human TransPacific Demonstration"*, JAPAN-U.S. SCIENCE, TECHNOLOGY & SPACE APPLICATIONS PROGRAM (JUSTSAP), Millennium Workshop, Kauai, Hawaii, November 1999.

Invited Presentation, Gill, M. Tatsumi, H. *"Visible Human Anatomical Collaboratory"*, Bridging the Gap Workshop, NASA Ames Research Center, Moffett Field, CA August 10, 1999.

Invited Talk, *"NGI Activities and Applications at the National Library of Medicine"*, CANARIE's Third Annual Workshop, Ottawa, Canada, December 15-16, 1998, Ottawa, Canada.

Other Professional:

-Technical Evaluation Reviewer for various NLM, NCRR, NCHS, NSF R&D grants and contracts
-Program reviewer for a NASA Advanced Networking R&D program (2004)
-Member of Internet2 Health Sciences Advisory Group (2000-2005)
-Mentor for NLM Adopt-A-School Outreach Initiative

Press coverage/quoted:

1. Jackson, William. "NLM tool does finger-pointing", Government Computer News, p. 41,44, June 12, 2000.
2. Silverstein, Sam. "International Test To Push Satellite Technology Limits", p. 13, Space News, May 15, 2000.
3. Breidenbach, Susan. "Future of High-Speed Networks", Network World, p. 67-8, February 14, 2000.
4. Garnett, Carla. "Ultra-Swift Internet2 Connection Now Available at NIH". The NIH Record Vol. LI, No. 14, p. 1, 6. July 13, 1999.
5. Garnett, Carla. "NIH Joins Next Generation Internet, Internet2 Development Efforts". The NIH Record Vol. L, No. 4, p. 6. February 24, 1998.

Curriculum Vitae

Susan E. Hauser
Electronics Engineer, Communications Engineering Branch, LHNCBC, NLM, NIH

Education, Training, Certification:

Phillips University	BA	1969	Mathematics
University of Wyoming	MS	1974	Bioengineering
University of Wyoming	PhD	1975	Bioengineering
NINCDS, NIH	Fellow	1974-8	Engineering
State of Maryland	Professional Engineer	1985	
IEEE	Senior Member	1999	

Research and Professional Experience:

- 1985 – Present. Electronics Engineer. Communications Engineering Branch, LHNCBC, NLM, NIH. Coordinate and conduct R&D in projects related to information delivery systems for handheld computers, document image understanding, OCR correction, and image data storage and transmission.
- 1984-5. Electrical Engineer. David Taylor Naval Ship Research and Development Center.
- 1982-4. Assistant Professor. Electrical Engineering Department, United States Naval Academy.
- 1978-82. Electronics Engineer. DCRT, NIH.

Publications *(peer-reviewed)***:**

- Demner-Fushman D, Few B, Hauser SE, Thoma GR. Automatically identifying health outcomes in MEDLINE records. JAMIA 2006 (to appear).
- Demner-Fushman D, Hauser SE, Thoma GR. The role of title, metadata and abstract in identifying clinically relevant journal articles. AMIA 2005 (to appear).
- Sutton VR, Hauser SE. Preliminary comparison of the SEER and PubMed search engines for answering clinical questions using PubMed on Tap, a PDA-based program for accessing biomedical literature AMIA 2005 (to appear).
- Alexander GL, Hauser SE, Steely K, Ford G, Demner-Fushman D. A usability study of the PubMed on Tap user interface for PDAs. MEDINFO. 2004;11(Pt2):1411-5.
- Demner-Fushman D, Hauser SE, Ford G, Thoma GR. Organizing literature information for clinical decision support. MEDINFO. 2004;11(Pt1):602-6.
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- Hauser SE, Berman LE, Thoma GR. Is the bang worth the buck? A RAID performance study. Proc the Fifth NASA Goddard Conference on Mass Storage Systems and Technologies. NASA Conference Publication 3340, September 1996, 131-140.
- Hauser SE, Gill MJ, Thoma GR. Document image archive transfer from DOS to Unix. Proc Fourth NASA Conference on Mass Storage Systems and Technologies, College Park, MD: NASA Conference Publication 3295, March 28-30, 1995; 105-113.
- Hauser SE, Roy G, Thoma GR. Optical disk jukebox performance in multi-user applications. Proc 1994 Optical Data Storage Topical meeting, Vol. 10. Optical Society of America, May 1994; 53-5
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Curriculum Vitae

Tri Quang Nguyen
Computer Clerk, Communications Engineering Branch, LHNCBC, NLM, NIH

Education and Training:

Montgomery College	A.A.	2001	Computer Science
University of Maryland University College	B.S.	2005	Computer Science

Research and Professional Experience:

2003-present Communications Engineering Branch, LHNCBC, NLM

- Assists in the development of the MD on Tap server application using Java, Tomcat, and MySQL. PubMed on Tap is an application for PDAs that facilitates Internet access to NLM's MEDLINE database using PubMed utilities.
- Assists and develops Java application that gathers statistical information for MD on Tap.
- Develops utility programs for MD on Tap. Utility programs include an automated program that updates the MD on Tap's persistence data, and an application that checks and reports error caused by the MD on Tap server.
- Assists in the development of CEB's Rover application. Rover is a visualization and analysis tool that allows researchers to compare their algorithms for segmentation of scanned medical journal articles, zone identifications, OCR character features, and data manipulations against a ground truth data set.

2002 eNumerate Solution Inc (McLean, Virginia)

- Assisted in developing an application that transforms ordinary data into Interactive Data Views, which can be posted on any Web site or intranet.
- Investigated and evaluated COTS and Open Source tools for use in enhancing eNumerate software.
- Published interactive data on the Web for PriceWaterhouseCooper and American Bankers Association.

Curriculum Vitae

George R. Thoma
Chief, Communications Engineering Branch, LHNCBC, NLM

Education and Training:

Swarthmore College	B.S.	1965	Electrical Engineering
University of Pennsylvania	M.S.	1967	Electrical Engineering
University of Pennsylvania	Ph.D.	1971	Electrical Engineering

Research and Professional Experience:

1984-present Chief, Communications Engineering Branch, LHNCBC, NLM

Directs and conducts R&D in projects involving document image analysis, biomedical image processing, image animation and communications engineering. Project descriptions and results appear in the published literature (see Publications), and are synopsized in the branch's Web page *http://archive.nlm.nih.gov*. Recent work includes the following:
Digital Preservation Research: Developed an initial prototype of a *System for the Preservation of Electronic Resources* (SPER) that possesses the essential functions of a digital preservation system including ingest, automated metadata extraction, transfer of metadata from other databases, and bulk file migration.
Interactive Publications Research: Began a project to investigate the technology to create a comprehensive, self-contained and platform-independent multimedia documents.
Medical Article Records System (MARS): Led the development and implementation of systems to automate the extraction of bibliographic records to build MEDLINE citations from both scanned as well as online journal articles (MARS and WebMARS). Initiated the design of systems to meet the goals of NLM's *Indexing 2015* initiative to increase the efficiency of creating citations for MEDLINE so that the expected doubling of the citation rate in a few years can be accommodated through automation.
TurningThePages: Animation/touchscreen technology for photorealistic rendition of rare books.
Biomedical Imaging Research: Internet-accessible multimedia database of digitized x-rays, uterine cervix images, histological images and associated text; content-based image indexing; online digital x-ray atlas; algorithms for image indexing by shape, texture and color features.
AnatQuest: end-user access to a database of Visible Human cryosection and rendered images.
DocView: research in document imaging for end-user Internet access to electronic documents.

1974-84 Senior Electronics Engineer, Communications Engineering Branch, LHNCBC
Conducted R&D in communications systems and signal processing techniques applied to electronic document storage, retrieval and display; biomedical image data compression, text recognition and image enhancement, satellite communications, echo suppression, videodisk premastering, motion-adaptive video compression.

1973-74 Systems Engineer, General Electric Co., Space Division, Valley Forge PA.
1971-73 Systems Engineer, AII Systems, Moorestown NJ.
1968-71 Ford Foundation Fellow, University Research Fellow and Post-doctoral Research Associate, University of Pennsylvania, Philadelphia

Honors

* General Chair, 14th IEEE Symposium on Computer-Based Medical Systems, 2001
* Fellow of the SPIE, International Society for Optical Engineering
* Awards: NIH Merit Award 1998, NLM Regents Award 1998, Federal Computer Week's *Federal 100 Award* 1995, NLM Staff Recognition Awards (1997-2002); On-the-spot Award (1998); Special Act/ Service Award (1997); Special Act Group Award (1992); Merit Awards (1984-97).
* Member, Internet2 Applications Strategy Council.
* Member, Maryland Governor's Task Force on High Speed Networks (1998- 2003).
* Keynote speaker at SPIE Electronic Imaging, San Jose CA, February 1996; and at 8th IEEE Symposium on Computer-based Medical Systems, Lubbock TX, June 1995.
* Member, Blue Ribbon Panel at NIST for document file format standards (1994-95).
* Invited referee for: IEEE Journal on Special Areas in Communications; IEEE Computer Journal; IEEE Parallel and Distributed Technology; Information Processing and Management Journal; Journal of Clinical Engineering; SPIE and IEEE conferences.
* Association of Image Information Management Certificate of Service (1995)
* American College of Physicians Certificate of Accomplishment (1993)
* NASA Certificate of Appreciation (1993)

Publications (2005 only):

Thoma GR. Public access to anatomic images. Chapter in: *Medical Informatics: Knowledge Management and Data Mining in Biomedicine*. Chen H, Fuller S, Friedman C, Hersh W, Eds., Norwell, MA: Springer Science + Business Media, 2005; 299-332.

Long LR, Antani SK, Thoma GR. Image informatics at a national research center. Computerized Medical Imaging and Graphics 29 (2005) 171-193.

Mao S, Misra D, Seamans J, Thoma GR. Design strategies for a prototype electronic preservation system for biomedical documents.Proc. IS&T Archiving 2005 Conference, Washington DC; April 2005; 48-53.

Walker FL, Thoma GR. Image preservation through PDF/A.Proc. IS&T Archiving 2005 Conference, Washington DC, April 2005; 259-63.

Antani SK, Natarajan M, Long JL, Long LR, Thoma GR. Developing a comprehensive system for content-based image retrieval of image and text from a national survey, Proc. SPIE Medical Imaging, February 2005; San Diego, CA; vol. 5748:152-161.

Antani SK, Long LR, Thoma GR. Applying vertebral boundary semantics to CBIR of digitized spine x-ray images. Proc. IS&T/SPIE Electronic Imaging, Conference on Storage and Retrieval Methods and Applications for Multimedia 2005. Lienhart RW, Babaguci N, Chang EY, Eds., January 2005, San Jose CA, SPIE Vol. 5682; 98-107.

APPENDIX B: QUESTIONS FOR THE BOARD

1. Is the current emphasis on research of design principles for point of care information delivery appropriate? Does the Board of Scientific Counselors recommend any additional directions or advice?

2. Is targeting and actively pursuing specific user groups rather than expanding the number of platforms/devices for which MD on Tap is available appropriate? How can we best recruit and collaborate with these groups?

3. What steps can MD on Tap take to recruit additional users and encourage feedback from them?

4. Do observational user studies accurately measure effectiveness of information delivery principles discovered and encoded in MD on Tap? What evaluation methods/techniques does the Board suggest?

5. How can MD on Tap and LHNCBC encourage collaborative informatics research with outside groups? What is the most appropriate form of such collaboration?

6. Should MD on Tap engage in outreach to underserved areas, or rather focus on introduction of the application to institutions that already have a well-supported infrastructure?

APPENDIX C: GLOSSARY

E-utilities	**Entrez Programming Utilities**. Tools that provide access to Entrez data outside of the regular web query interface and may be helpful for retrieving search results for future use in another environment.
HTML	**HyperText Markup Language.** A markup language designed for the creation of web pages and other information viewable in a browser. HTML is used to structure information -- denoting certain text as headings, paragraphs, lists and so on.
HTTP	**HyperText Transfer Protocol.** A request/response protocol between clients and servers. The primary method used to convey information on the World Wide Web.
J2ME	**Java 2 Platform, Micro Edition.** A collection of Java APIs targeting embedded consumer products such as PDAs, cell phones and other consumer appliances.
KVM	**K Virtual Machine.** A recent Java virtual machine introduced by Sun, designed for small-memory limited-resource connected devices such as cellular phones, pagers, PDAs, set-top boxes, and point-of-sale terminals.
mySQL	**My Structured Query Language**. A multithreaded, multi-user, Structured Query Language Database Management System, available as open source software.
NCBI	**National Center for Biotechnology Information**, a Division of the National Library of Medicine. Its mission is to create public databases, conduct research in computational biology, develop software tools for analyzing genome data, and disseminate biomedical information.
NIST	**National Institute of Standards and Technology.** A non-regulatory agency of the United States Department of Commerce. Its mission is to develop and promote measurement, standards, and technology to enhance productivity, facilitate trade, and improve the quality of life.
PDA	**Personal Digital Assistant.** Handheld devices that were originally designed as personal organizers, but have became much more versatile over the years.
Smartphone	Any handheld device that integrates personal information management and mobile phone capabilities in the same device. This includes adding phone functions to already capable PDAs or putting PDA functions, into a mobile phone.
UMLS	**Unified Medical Language System.** A combination of knowledge sources used to facilitate the development of computer systems that behave as if they "understand" the meaning of the language of biomedicine and health. Produced and distributed by the national Library of Medicine.
UNIX	A computer operating system originally developed in the 1960s and 1970s by a group of AT&T Bell Labs employees, designed to be portable, multi-tasking and multi-user.
URL	**Uniform Resource Locator.** A standardized address name layout for resources (such as documents or images) on the Internet (or elsewhere). The currently used forms are detailed by Internet standard RFC 1738
WiFi	Short for "**Wireless Fidelity**". A set of product compatibility standards for wireless local area networks (WLAN) based on the IEEE 802.11 specifications. Intended to be used for mobile devices and LANs, but is now often used for Internet access.
XML	**Extensible Markup Language.** A general-purpose markup language for creating special-purpose markup languages, capable of describing many different kinds of data. Its primary purpose is to facilitate the sharing of data across different systems, allowing programs to modify and validate XML documents without prior knowledge of their form.