Samvidha: A ICT System for Personalized Offline Internet Access for Rural Schools

Plaban K. Bhowmick, Samiran Sarkar, Sunandan Chakraborty, Sudeshna Sarkar, and Anupam Basu

***Abstract*—Internet is a huge repository of quality learning materials and continues to grow in a faster rate. The school students may be benefited immensely as these learning materials may well supplement their curricular requirements. But Access to the Internet is costly, because it is very expensive to maintain a persistent Internet connection. For some schools in the developing countries like India, this cost may not be affordable specifically in rural schools. This makes way to a digital divide between the rural and urban schools which is unwanted. For these rural schools, limiting the amount of bandwidth consumed is of paramount importance. It is necessary that the schools be connected to the Internet for the least time, in order to minimize the access cost. In this paper, we present a system *Samvidha* that allows the rural school students to access the Internet contents in an offline fashion.**

***Index Terms*—Information and communication technology, offline Internet access, personalized information filtering, school education, user modeling.**

I. Introduction

THE advent of Internet technology has brought about a great revolution in information dissemination. It has added a new dimension to the educational infrastructure and has been a huge resource of educational contents. Computers are widely used in rendering multimedia contents. It has proved to be effective in storing and organizing a large amount of information. Innovation in the electronic media has offered new and effective modes of rendering information in educational settings. But the wave of this revolution has not yet touched a substantial section of users especially in the rural academic arenas of third world countries. The situation is changing now in India. A Working Group on Information Technology for Masses was established by the Government of India in May 2000 to address these issues. Encouraging resolutions were taken to promote Information Technology for education [1].

The IT policies of the Government for education have brought about a modernization of the educational scenario in schools of India. Many schools in India have acquired computer infrastructures and Internet connectivity. Yet access to the Internet is still a dream to the rural section mostly because of the lack of viable technology to cope up with the problem of bad infrastructure and high cost involved. This fact is well supported by [1]. In this paper, we report a system that we have developed to enable students in rural India to get access to information from Internet.

Some of the problems that hinder the percolation of the desired effect of the Internet technology in rural area are

- Due to the vastness of information in Web and ambiguity in search results in response to queries, finding specific information from this huge pool is tedious and time consuming. If a student has to sift through a huge number of results to find documents of her interest, she may get bored without finding the information she needs.
- Due to the lack of proper infrastructure, dial-up connection is the commonly used mode of connection to the Internet in rural schools. The cost of Internet access in this case is proportional to the amount of time the connection is up. A considerable amount of time is needed to search, download or read particular information online, increasing the connection cost.
- The number of students in a school is usually large. In order to provide Internet access to all the students, the school has to arrange different slots for different students. Search from the Internet involves selecting and reading documents and needs a sufficient amount of time. To satisfy each student who have individual information needs, the school has to be connected to the Internet for a whole lot of time. The cost of accessing the Internet is proportional to the amount of total time the school computer is connected to it. For all students in the school, the total cost becomes enormous and in most of the cases unaffordable for the rural schools.
- Sometimes the Internet may not be available to the students for various reasons. For example, the Internet connection may not be up due to the unreliability of the communication channel or the decision taken by the school authority to limit the Internet access to the students to cut down the cost.
- The students in rural India may not be well acquainted with the computer systems. Complex systems may shift their focus from the curricular related activities and also may cause psychological hindrances (fear, shyness) to access the system.

In this paper, we present a technology to deal with these problems. We have developed this system to let the users in schools access information from the Internet as also from locally available documents. The basic objectives of the system are

- *Cost minimization*: The cost of accessing Internet has to

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be minimized which can be achieved if we can use the bandwidth in an optimal way.

- *Student satisfaction*: To satisfy the students, only items that are relevant to the students have to be presented. The response time (time between query submission and result availability) should be minimum.
- *Effective search interfaces*: The search interface should be simple and intuitive.

The system will enable the schools to utilize its limited infrastructure and still provide access to a large number of students. We note that the system should have the following features:

- *Reduction in information overload*: It is often the case that in response to a query a user is flooded with tens of thousands of references to Web documents. Ineffability and tiredness in searching for relevant information is a direct consequence of this information overload. We will like to identify only information that is relevant from the user's perspective. This will improve student satisfaction. Providing only relevant documents and downloading those will lead to less bandwidth requirement and hence will reduce the cost of information access to great deal. To achieve this, the system will need to have two important knowledge sources: knowledge about the domain of search and knowledge of user's requirements.
- *Offline access to information*: Online access of information on the Web needs a persistent Internet connection. The persistence of connection depends on the communication channel and the available bandwidth. But in most rural areas of a country like India, this amount of bandwidth is either not available or not affordable. We have aimed at providing a software system in schools which will facilitate the access to information in an offline fashion. The offline access of information has got another benefit as it is a way to reduce the cost of accessing information.
  The computer-student ratio in schools being usually low, every student cannot get sufficient access to the Internet. Further most of the schools do not encourage the students to use Internet due to the cost factor in accessing Internet. The main tasks involved in an Internet search process are
  - Task I: Querying the Internet
  - Task II: Finding and downloading relevant items.
  - Task III: Reading relevant items.

  In online access to information, the process is interactive and all the tasks are carried out in one session. For the entire duration of the session a persistent and reliable connection is needed and it demands a large cost. This motivates us to think of a less interactive model where the tasks are distributed to different servers. *Task I* and *Task III* are tasks that can be performed without Internet connectivity provided Task II is done by another server that is having a persistent connection and the yield of *Task II* can be used to achieve *Task III*. This will certainly reduce the Internet access cost in schools as most of the time consuming tasks are performed in offline.
  In order to cater to the information need of this large number of students, we need to establish a set up where multiple users can access the system simultaneously and users can use this facility from any of the computers in the school. This can be handled by setting up a client server based system in schools.
  We further observe that the information need for students may overlap. A survey has been performed where the students were asked individually to provide 20 queries. 90 queries were collected, in which approximately 50 distinct instances of queries were found. The bandwidth will be optimally utilized if the Internet contents for the previously placed queries are stored in school locally. Once the information is available locally, the system does not need to go for Internet search for similar queries. This has the following two advantages.
  - Optimal use of bandwidth leads to minimization of cost.
  - Response time for the locally available information will be much less. The students will feel more satisfied.
- Effective search interface :Provision of effective and easy to use user interfaces a very important design criterion. As most of our target users are not well acquainted with the Internet search process, the users may be feeling inconvenient to access the system. For example they may not be able to formulate the queries properly. For this we aim at designing an *offline browser* that will help the users to carry on the search process easily.

The salient contributions of this work are as follows.

- A system for offline Internet access.
- Modeling of domain knowledge for concept based information filtering.
- User modeling for personalized information access.
- Design of simple access interfaces for rural school students.

In section 2, some of the works related to the offline access of Internet contents are discussed. In section 3, we provide an overview of the system. In section 4, we describe different technical aspects related to Samvidha system. We discuss about the deployment of the system and some results in section 5. In section 6, a case study of Sarani, one of our deployment centers, is presented.

II. Related Works

There are a number of offline search engines, which address the issue of low-bandwidth connectivity. Some of these systems provides access to Internet through email.
GetWeb [2], www4mail [3] and Web2Mail [4] are some email based services that return text representation of a given web page. Instead of downloading the actual contents, these services return URL lists in response to the user queries. Google Email Alert[1] delivers customized news based on the user specified queries.
TEK [5], developed at MIT, is client-server based system to provide offline access to the Internet. The users can provide

[1] http://www.google.com/alerts

queries through browser. The queries are forwarded to the server by administrator. The server return a set of documents from the Web through email. The administrator in the client end extracts the documents from the email and the users can view the documents through the browser.
All the systems discussed above return the documents retrieved by the base search engine without looking at the users' interests and domain relevance and may return a large number of irrelevant documents.

III. System Overview and Usage Perspective

We developed a system, Samvidha, that aims at providing school curriculum related information to the students in an offline manner. The information flow of this system is depicted in Fig. 1. One *Central Server* can cater to a number of schools. This server is always connected to the Internet through high bandwidth connection so that it becomes always available to process the requests from different schools. In every school, there is a setup called the *School Client*. Within the *School Client* setup, there is a client-server model having two distinct entities.

- *Local Server :*One machine in the school is setup in server mode, which is responsible for handling the requests from Local Clients.
- *Local Client :*One or more than one machine can act as Local Client in a school, through which the students can place the requests to the Local Server and browse the contents available in the Local Server.

The Following steps are involved while accessing the system.

- The students can place their queries from any Local Client terminal in the School Client.
- The queries are queued up in the Local Server.
- When the Internet connection is available, the queries are forwarded to the Central Server in a burst mode through e-mail.
- The Central Server parses the query mails and looks at the student's preferences stored in the server to collect appropriate school curriculum related study materials from the Internet using Google as the search provider.
- The relevant materials are packaged and mailed for the proper School Client.
- When the Internet connection is available at the School Client, the available response emails are received.
- The packaged study materials are extracted and stored into the local repository.
- The students can view the extracted results without being connected to the Internet.
- This system also provides the option for local search to minimizing the interaction with the Internet.

IV. Technical Perspective

In this section, we discuss about some of the technical aspects of the system.

A. *Communication Protocol for Offline Access*

Samvidha has been implemented in three tier architecture using Java Mail, Java Servlet and MySQL database technology. The communication protocol of this system is given in Fig. 2. The Local Client is implemented entirely through Java Swing. This includes query submission interface, result browsing interface and user profiling interface. The exchange of queries and results between the Local Server and Local Clients is mediated through HTTP protocol. The Local Server and the Local Client uses a common database situated in the Local Server and it is implemented in MySQL. The database mainly comprises of data regarding authentication, domain knowledge, user model, syllabus, query. In each session, behavior of the students are tracked by monitoring the browsing pattern, events of user interaction e.g., mouse click. Student behavior data for each session is communicated to the Local Server through HTTP request and stored in XML format. These session records are analyzed later by the monitor daemon to update the user models. The mailer daemon, implemented in Java Mail, sends the pending queries to the Central Server and receives the available results when it is connected to the Internet. The students can also search the local repository that is gradually populated by Internet contents received in response to previous queries. The local repository search has been implemented through the keyword based search engine Lucene [6]. On receiving the query, the Central Server forwards the query to Google and filters out the irrelevant results consulting domain knowledge and user profile stored in the server database. The relevant links are downloaded with the help of a crawler. The crawled results are packaged to form an attachment. The attachment is mailed to the client by the mailer daemon implemented in Java Mail.

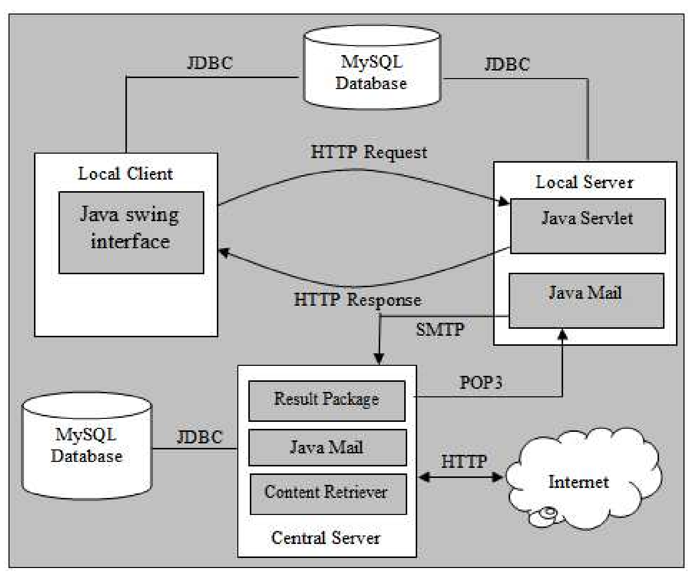


Fig. 2. Communication protocol of the system

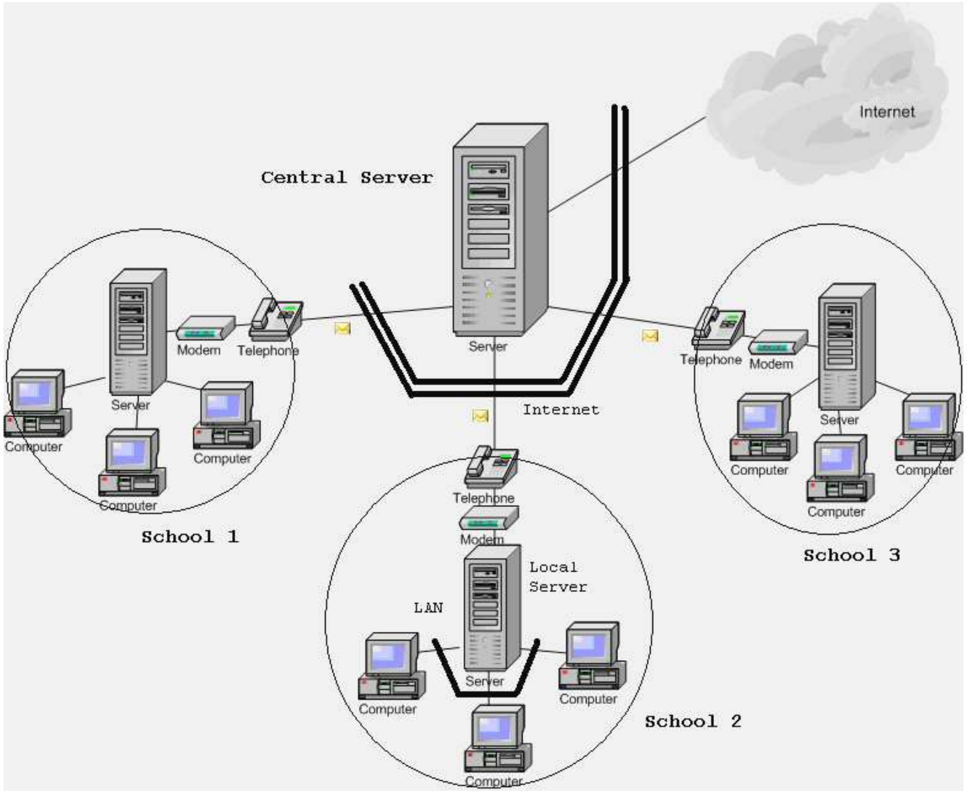


Fig. 1. Information flow of the system

B. Domain Knowledge and User Model

In the field of information retrieval knowledge based domain specific approaches have play a very important part. The presence of domain knowledge helps to achieve higher precision in retrieval. We need an extensive representation of knowledge of the domain for which information retrieval is required. Formally domain knowledge is represented through ontology [7]. Since it is difficult to build up ontologies, we have restricted ourselves to some limited domains related to the curriculum related subjects in schools.
The school curriculum related domain has a particular structure. School curriculum consists of several subjects. A typical study material on a subject is an organization of several chapters. Each chapter may be divided into sub-chapters. Each chapter describes one or more than one topic(s). Each chapter consists of several concepts that deals with the topic representing the chapter. The concepts of a domain are related to other concepts of the domain through different concepts. One particular concept may be referenced by some synonymous terms. Keeping in view of this particular kind of domain structure, we represent the domain knowledge in a three tier model as shown in Fig. 3.

- **Concept Level:** This level represents the ontological concepts. A set of empirical *relations* can be defined among the concepts in a domain. These relations provide a means to capture semantic content of the textual documents. We notice that if a concept is of significance in a document, it is usually the case that the document contains a number of references to related concepts. For example, if a document contains material relevant to reflection in optics, it will have references to some of the *related concepts* like light, ray, mirror, lens, angle of incidence, etc. Our idea is to score a concept by looking at references to that concept as well as to related concepts.This enables us to relate one concept to a number of related concepts with different degree of strength. Currently there are 11 distinct relations present in our ontology as shown in Table I.

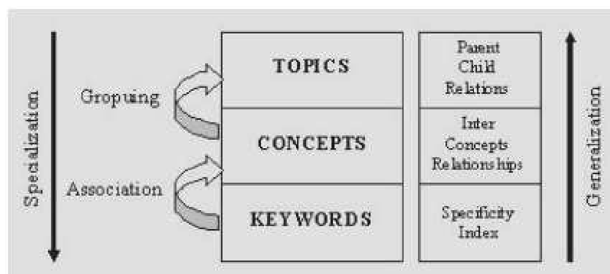


Fig. 3. Knowledge model in Samvidha

TABLE I
FORWARD AND REVERSE RELATIONSHIPS

Forward Relation	Reverse Relation
Has Part	Part Of
Inherited From	Parent Of
Has Prerequisite	Prerequisite For
Part of Procedure	Procedure Contains
Is Caused By	Causes
Functionally Related	Functionally Related

- **Topic Level:** On the top level, the topics share a parent child relationship. This provides a way of generalization from a specific to a more general topic. The hierarchy of the topics is stored as an n-ary tree with the exception that a node may have multiple parents. This is because a subtopic may be placed under two or more topics. Concepts in the middle tier are grouped to the topics.
- **Keyword Level:** At the keyword level of the knowledge representation, important words that are found in a document are stored. These keywords are indicative of concepts. However the same word may refer to more than one concept, though usually only one sense of the word is indicated in a given context.

The domain knowledge alone is not enough to collect information specific to the need of a particular user. The system should have a model of the user's interest to meet the user's need. User modeling is the task of creating the model of the user in terms of her goal, preferences, likes and dislikes etc [8]. Here we have adopted an ontology based user modeling approach [9]–[12]. The same ontological structure has been adopted while representing user profile. Students belonging to the same class have a common set of interests that are defined by the curriculum. This reflects the knowledge requirements for a specific user group. This common requirement has been represented in the form of *group profile*. A student may adopt one or more group profiles as her initial profile and can edit the profile to customize to her needs. These user profiles are updated according to the students' shifting interests. The dynamic update in user profile is achieved through modeling the browsing behavior of the students. The user models are learned based on the following data sources:

- Query history.
- Link access behavior.
- Contents accessed by the user.
- Usage log which includes the content browsing structure, mouse events, time spent on contents etc.

The monitoring agent in the Local Server analyzes the Usage logs and data sources and assign interest scores to the existing and discovered concepts through a set of concept scoring functions. The monitoring agent depends on a decay function to penalize the user profile concepts which are not addressed by the student for long enough time.

C. Ontology based Personalized Information Filtering

Information filtering in Samvidha is performed in the Central Server with the help of user profile and the group profile. The filtering is performed if the domain of the query is one for which ontology is available with the system. Currently we have populated domain ontology for physics, biology and geography. If the query does not belong the domain of our scope, the system will bypass this module and return the first N documents returned by Google. Connection to Google is handled with Google SOAP APIs[2]. Currently, the system is able to handle text and HTML documents.
Three different scores are calculated to decide on the relevance of a document.

[2]http://code.google.com/apis/soapsearch/reference.html

- *Query Relevance Score*: It gives the measure of relevance of the document with respect to the query. The frequency of occurrence of a concept is sometimes used to find the importance of the concept. However, it has been observed that an important concept may not occur frequently in a document. The presence of related concepts to the query concepts in the document may be a true indicative of the significance of the query concept.
- *User Interest Score*: It measures the degree of match between the user profile concepts and the document concepts.
- *Group Interest Score*: The relevance of the document with respect to the group profile that the student belongs to.

The final content score is obtained by combining the query relevance score, user interest score and the group interest score. The server then downloads the relevant portions of the URL containing relevant pages through a focused crawler.

D. User interfaces

In our system, the primary focus is to design very simple interfaces as most of the users of our system are not computer literate. Here we provide the description details of some important interfaces. We mainly focus on the offline browser the basic aim of which is to simplify the procedure of accessing information. It consists of mainly two parts.

- *Visual Query Submission Interface*: A screenshot of this interface is shown in Fig 4. The users can simply type in the queries in the *Query Panel*. But all users may not be able to type the queries properly. So we have provided the option for formulating the query through a visual interface. There are two types of visual interfaces: *Tree Viewer* and *Concept Space Viewer*. The *Tree Viewer* renders the domain knowledge in a expandable tree view where sub-topics and concepts of a topic are rendered as the children of the topic. Users can select any concept from this tree and add to the query string by clicking on the *Query Add* button. The *Concept Space Viewer* provides a visual representation of a small part of the concept space. The rural students are easy with communicating in vernacular. So, we provide vernacular interface for formulating queries.
  Student may opt for *Local Search* or *Internet Search*. Local search options provides the students with documents retrieved from the local repository promptly. In Internet search option query is queued in the local server.
- *Result Browsing Interface*: This component of the offline browser renders the results collected in response to student queries. This interface is totally managed by Java servlet which establishes an HTTP connection between the *Local Client* and the Local Server. It is initialized with the page which contains the list of queries placed by the user along with their status (Fig. 5). The results for each query can be accessed by following the link associated with the query. Each processed query is linked with the page consisting of titles of the downloaded documents (Fig. 6). The actual document can be viewed by clicking the hyperlink associated with each title (Fig. 7).

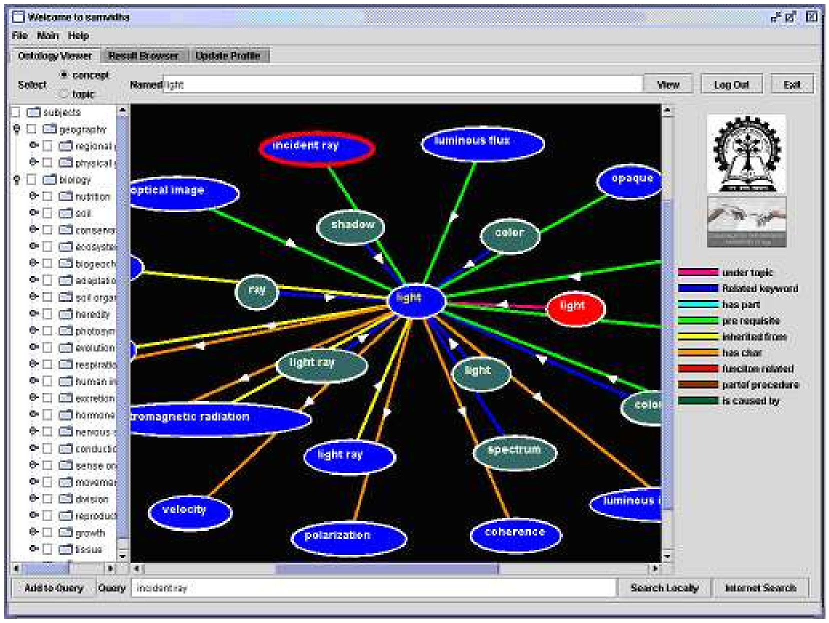
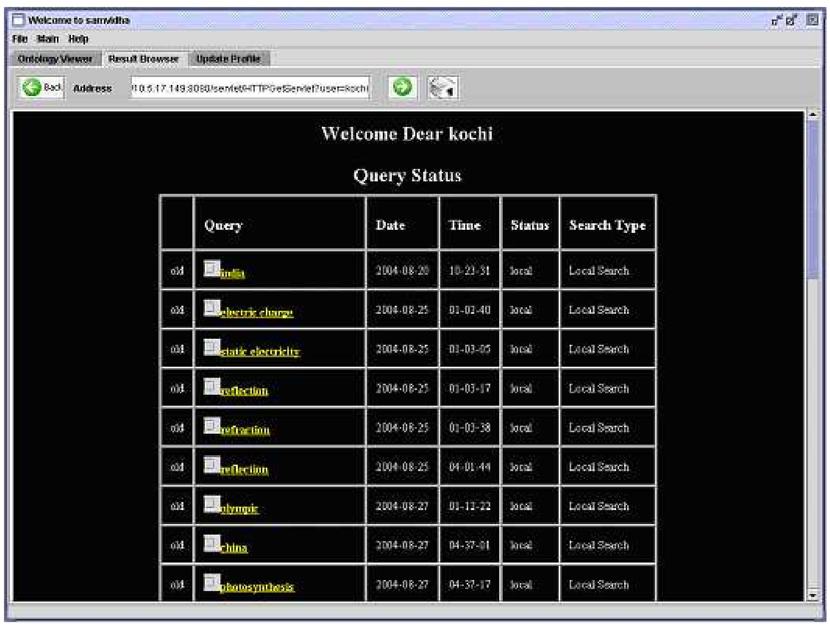


Fig. 4. Query submission interface



	Query	Date	Time	Status	Search Type
old	india	2004-08-20	10-23-31	local	Local Search
old	electric charge	2004-08-25	01-02-40	local	Local Search
old	static electricity	2004-08-25	01-03-05	local	Local Search
old	reflection	2004-08-25	01-03-17	local	Local Search
old	refraction	2004-08-25	01-03-38	local	Local Search
old	reflection	2004-08-25	04-01-44	local	Local Search
old	olympic	2004-08-27	01-12-22	local	Local Search
old	china	2004-08-27	04-37-01	local	Local Search
old	photosynthesis	2004-08-27	04-37-17	local	Local Search

Fig. 5. Result browser interface

The result browser is able to capture the students' behaviors during the browsing sessions. It keeps track of the browsing paths for the students. It also tracks clues like time spent by a student on a particular page, mouse activities of a student on the browser and stores them in the form of usage log which is analyzed to update the user models. The browser is also capable of rendering pdf and microsoft word documents.

V. Deployment and Results

The system uses Google search engine as its base system. The documents returned by Google are filtered using domain ontology and the user profile. Here we present an experiment to validate the effectiveness of the ontology based personalized content filtering module. We also present a study on the *response time* of the system defined as the time elapsed between the invocation of the student query and the delivery of the documents by the central server.

A. Deployment

The experiments have been carried out in three deployment centers set up by Communication Empowerment Laboratory, IIT Kharagpur[3]. The deployment centers include

- DAV Model School, IIT Kharagpur.

[3] http://www.cel.iitkgp.ernet.in/

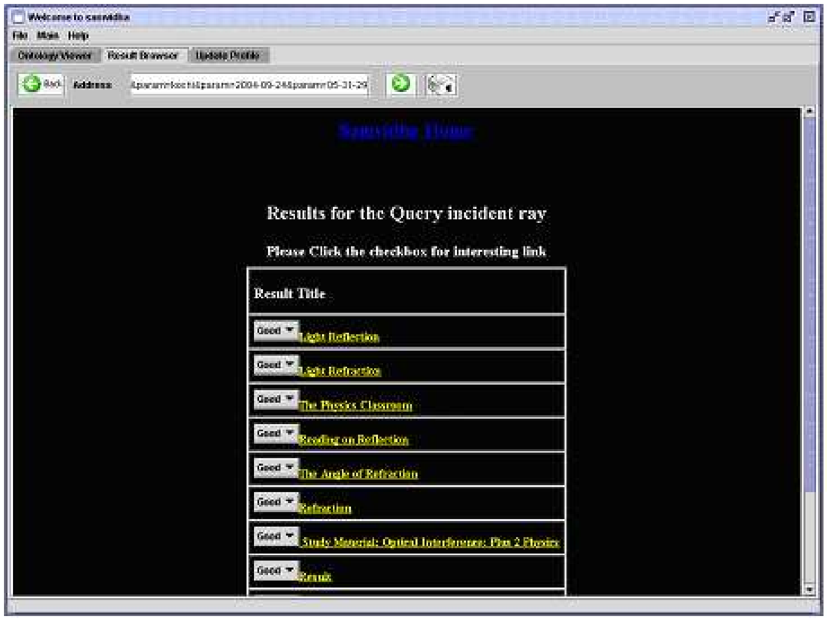


Fig. 6. Links to results for a user query

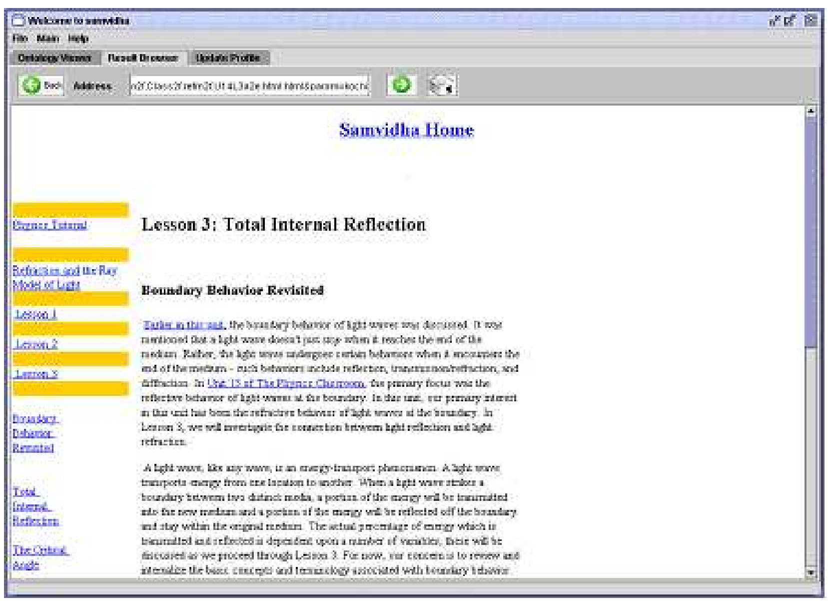


Fig. 7. Actual document returned for a query

- Hijli School, IIT Kharagpur.
- Sarani Computer Center, Ghantal subdivision.

B. Experiment 1: Effectiveness of Content Filtering Module

The students from 9^{th} to 12^{th} standard were asked to provide queries of their interest in the subjects of Physics, Biology and Geography. Our experiment was restricted to 78 queries provided by the students. The queries were processed by Samvidha and the resulted documents were presented to the students. The students were then asked to mark each document with *relevant/irrelevant* tags. On this basis, we computed the precision of the retrieved results.

The students were also asked to rank the first 20 documents returned by Google in response to the same set of queries. Each document was marked in same way and the precision values were computed. The average precision of the base system (Google) is 50.83% and the average precision computed for our system is 76.66%. Analyzing the precision value of each of the queries, we have observed the following facts.

- There is a set of queries for which Google retrieves documents with relatively low precision values. Examples of these kind of queries are *light, reflection, gravity, force, vitamin, glucose,* etc. In this case, the queries are too general and ambiguous in nature. For these set of queries, average precision of Google is 24.60% and the precision of our system is 74.02%.
- There exists another set for which Google has high precision in the retrieval process. Example queries are

electric charge, newton's laws of motion, reflection and refraction, charge conduction conductor, etc. In this case the queries are most of the cases multi-word queries and specific enough to retrieve the relevant documents. The improvement in precision value in this case is less. The average precision of Google is 63.20% and the that of our system is 77.91%.
- We also observed that for some of the queries the precision of our system is less than that of Google. On closer inspection, this discrepancy may be attributed to the incompleteness of our ontology.

C. Experiment 2: Estimate of Connection Time in School Client

The response time depends on

- *T1*: Time taken to send the queries to the central server.
- *T2*: Processing of the queries by the central server.
- *T3*: Time taken to send the documents to the clients
- *T4*: Time taken to extract the documents from mail attachments.

T2 and *T3* depends on the central server configuration and can be tuned by changing the server parameters. *T1* and *T4* depends on the connectivity between the clients and the central server. The cost incurred due to *T1* and *T4* is of main interest to a school. We give a measure of *T1*and *T4* time considering the following parameters.

- *Number of queries*: 100.
- *Average size of query mail*: 4 kilo bytes.
- *Number of documents to be downloaded/query*: It is set to 20.
- *Depth explored by the crawler*: It is set to 1.
- *Average document size*: It is assumed to 40 kilo bytes.
- *Average connection speed*: It is assumed to be 25 kilo bits per second.

Assuming the above mentioned values for different parameters, *T1* is computed approximately to be 2 minutes which is negligible. *T4* is estimated to be around 7 hours. So the school client has to be connected to the Internet for 7 hours to process 100 queries. This provides the upper bound of the connection time for the assumed values of the parameters because the central sever collect the documents and compress them to form a package having size much less than the cumulative size of total documents. So, the connection time is much less in this case as compared to an online system. This will cut down the cost of accessing Internet contents.

VI. Sarani: A Case Study

Sarani Computer Center is a co-operative formed by the villagers from five surrounding villages in Paschim Medinipur, West Bengal. It is working for a noble cause of rural development, literacy, health and general awareness and rural education. They have established a computer infrastructure that is being used the village students. The center is surrounded by two rivers thus creating an inaccessibility problem. For this reason, the access to Internet is through dial-up connection. As the Internet access cost is high in the context of the economic conditions of the village people, the Internet access facility was restricted to a very few high priority official jobs only. Thus the students of this locality were being deprived of the good quality study materials that are available on Internet. But the scenario has changed since Samvidha was installed at this center. The students are now finding it beneficial as they receive learning materials from Internet and the governing body of Sarani are happy as the cost incurred to provide students with Internet contents is much less. Fig. 8 shows students working with the Samvidha system in this center.

Fig. 8. Students using Samvidha at Sarani

VII. Conclusions

As the usage of Internet continues to grow, the quality of the network infrastructures in different countries will be better in the near future. In this paper, we address the problem of how to exchange relevant and rich contents of digital information across an unreliable, low-bandwidth, low connectivity communication network and present them in an offline fashion. We have presented an offline Internet access system which works through email, and different modules in that are present in the server to return personalized contents to the students. This system proved to beneficial particularly to the rural students and teachers who have very limited exposure to the current information revolution brought about by current Internet technology. Even if better connectivity is available to the addressed user community, the system can be tailored to obtain personalized digital content from the Internet.

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