TroTro: Web Browsing and User Interfaces in Rural Ghana

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ABSTRACT
The quality of Internet connections around the world is extremely varied and very poor in rural areas despite high enthusiasm and investment of resources in computers. This study focuses on Internet users at schools and Internet cafés in rural Ghana. We wished to explore whether there were challenges to Internet use in addition to the poor connection quality itself. In our study we found that beyond connectivity, the lack of computer knowledge, poor usability of web interfaces, and "foreignization" of technology compounded the problem. To improve web access in these contexts, we designed TroTro, a browsing system that maintains a usable experience despite fluctuating connectivity and a wide range of user expertise. We followed web usability heuristics in our design and our results show evidence that our system allows both novice and expert computer users to enhance their individual web experience, explore content across different kinds of network conditions, and share resources within their community.

Author Keywords
Internet; developing regions; web; information access; poor connectivity

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

General Terms
Human Factors

1. INTRODUCTION
The vast majority of Internet infrastructure is designed with the assumption that there is good network connectivity. Unfortunately, the quality of Internet access around the world is extremely varied. In poor connectivity areas the Internet can be expensive, slow, unreliable, and unavailable [3, 6]. Low population density in many developing regions makes it economically difficult to justify laying fiber or installing mobile data networks. Even in urban areas, high network congestion and outages occur frequently due to service provider downtime or human error [3, 5]. There are also many other scenarios where travelers enter another country outside their service providers' coverage. We consider these spaces where Internet access is temporarily or permanently limited. These spaces are likely to persist in the future because Internet content growth in size and complexity drastically outpace the rate at which infrastructure is deployed.

Like the rest of the Internet architecture the vast majority of user interfaces are designed based on the assumption that there is good connectivity. In the research literature systems have been proposed to address the connectivity problem by optimizing the connection in various ways [5, 17, 23], but few works have explored user interface design issues associated with web browsing. In this work we focus on the user interface of web browsers and design TroTro, a web browsing tool that allows users to search and browse web contents despite differences and fluctuations in connectivity and user expertise. We based our system on lessons learned in the research literature and our own previous field experiences. We conducted a user study in Hohoe, a rural village in Ghana, where locals encounter a variety of poor Internet connections and we iterated on our design.

We have three major contributions. First, we describe the characteristics of Internet and technology usage in Hohoe and how they informed our design decisions. Second, we discuss the features of TroTro and evaluate them via usability testing with local Internet users. Third, we suggest general usability heuristics for designing interfaces for similar contexts where connectivity and expertise are low.

We begin by reviewing the related work on enabling Internet and information access. We then go on to describe our user study explain how our study informed the design of TroTro. Finally, we present the results of our usability testing, redesign, and discuss the lessons we learned.

2. RELATED WORK
Many technologies have been used for enabling or improving information access and dissemination in regions with poor Internet connectivity. These systems span a range of application domains including: agriculture, health, education, market prices, and disaster relief [6, 13, 22]. These works generally attempt to solve a technical problem to improve socioeconomic shortcomings in a way that satisfies thematic information and communication

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technology for development (ICT4D) requirements such as sustainability and appropriateness.

PC-kiosks and telecenters are one common ICT4D. Kiosks are set up as a network intermediary in rural villages and are usually introduced with trained kiosk operators. E-Choupal, for example, provides kiosks with Internet access in rural areas of India [12]. PC kiosks are difficult to sustain due to high maintenance costs, poor infrastructure, and social barriers [16].

Information access via Short Message Service (SMS) is another medium for transferring information. Because of the high adoption rate of mobile technologies, many recent ICT4D projects have been focused on developing SMS systems in poor connectivity areas. SMS applications typically allow the users to send queries through SMS messages, usually in a predefined syntax, and receive responses in the form of SMS messages. Examples include Warana Unwired that tracks information in an India sugarcane cooperative [24], Tweek the Tweet, collected user-reported data during the recent Haitian earthquake [22], and Esoko service that provides Ghanaian farmers with market prices and agricultural information [13]. The SMS messages have a much lower barrier for entry, but are extremely constrained by the tiny 140 byte SMS payload.

Specific to web browsing, several systems and techniques have been proposed in recent years to inform the user about or optimize web browsing over poor network connections [5, 6, 9, 15, 16, 23]. Most systems address a particular networking problem in a particular context (e.g. text only browsing for low bandwidth connections [16], aggressive caching and prefetching within a Firefox addon for hard to deploy scenarios [5]). TEK [23] and RuralCafe [7] are general systems for web browsing over poor connections, but their contributions are mainly focused on network/application layer components that mediate between the slow connection and the user not the user interface itself. In terms of their user interfaces, these systems also include support local search and request queuing, but do not isolate and examine the usability their user interface elements.

Many of these works actually do manage to solve the technical challenge, but very few make it past the pilot phase. We believe, like a recent work by Wyche et. al. [27], that "ICT interventions should be grounded in users' existing practices rather than introducing new and unfamiliar ones." One major component of users' existing practices is their interaction with the user interface. Often these are "deliberate interactions" that must be planned in advance due to their *in*convenience [26]. While there are many studies on Internet and computer use [5, 8, 15, 16, 21, 23], we are not aware of any previous work that focuses on the existing practice and appropriateness of web browser user interface metaphors in these contexts. The closest work is from Medhi et. al. that looks at graphical user interface representations for illiterate and semi-literate users on mobile phone applications [18].

3. USER STUDY

To understand the problems faced by Internet users in poor connectivity areas and the tactics they use to deal with the slow connections, we conducted a field study in Hohoe, the capital town of mountainous Hohoe Municipality of Volta Region of Ghana. The town is chosen primarily because of its poor Internet infrastructure and relative lack of existing interventions and NGOs. Our project does not seek to directly promote the use of computer and Internet technology. Instead, it tries to improve the browsing and searching experience for those who have existing interests and needs for information access. The schools we visited did not always have Internet, but they did have computers and our participants had all used the Internet before. The user study uses mixed methods to explore the problem space.

3.1 Methodology

We conducted two previous one week visits to Hohoe in February 2012 to meet some local contacts and we conducted one month of field work in June/July 2012. For our user study we visited schools and Internet cafés in Hohoe because these were the two major types of public spaces for locals to use computers. The schools were selected through our contacts and we visited all four Internet cafes in Hohoe, but we eventually focused on the most popular Internet café. During our study, we observed two ICT classes, visited four Internet cafés, interviewed twelve participants, and held two focus groups. We took field notes and then used them to coalesce common themes and explore issues.

The first school we visited was a private commercial college with about 250 students. It had one computer lab and 53 second hand computers, which was said to be the highest number of computers owned by a school in Hohoe. There was, however, no Internet connection at the school. The school employed one temporary computer teacher who taught all the ICT courses. Students were enrolled in a two-year business program, and the ICT courses offered by the school taught theoretical and practical knowledge of Microsoft Office and basic computer hardware. Many students remarked that the ICT course was their favorite.

The second school was similar to the first, except it was a public secondary school with over 2000 students. They had two computer labs, but the second lab was not functional. There were also five less-than-perfectly functioning computers in the first lab due to a recent flooding of the room. Each computer processed input and output to eight monitors, keyboards, and mice. This technology provided the class with approximately 40 computer stations. Though the computers were connected in a LAN by a switch, there was no Internet connection available. There were five computer teachers at this school, and some of them had their own modems to connect to the Internet.

3.2 Participants and Procedures

We used a convenience sample of users for our study that may not be representative to the whole Hohoe community because our goal was to understand and serve the needs of current or potential Internet users in rural Ghana. As a result, we selected interview participants with different levels of expertise in Internet technologies to cover a variety of aspects about Internet use. When we were selecting the participants for usability tests, we also recruited people from the Internet café at different times of day and on two different days. Thus the people we studies are not limited by their availability at given time and day. The venues we chose to conduct the studies are common locations for locals to access Internet. Therefore, there is little reason to believe that this convenience sample would behave in a substantially different way than a random sample of Internet users in Hohoe.

In total, 16 locals, recruited from different locations in Hohoe, participated in our user study. Six subjects were chosen from amongst the student body (approx. age 14-18) and faculty (approx. age 20 – 50) of the two observed schools. These six were chosen based on whether they had desire to use the Internet and such that the research sample would elicit the views of users with diverse interests. Specifically, they included a school principal, a computer teacher who had a personal modem (M), a computer teacher who did not have a personal modem (MØ), a non-computer teacher who was interested in ICT (T), a student who was a novice computer user (N), and a student who was a computer enthusiast (F). These six participants took part in 1-on-1 semi-structured interviews regarding basic use of computers and Internet. We explored the different issues and needs of each individual.

We also visited all four Internet cafés in Hohoe. Three of them used dialup modems and one used an ADSL connection. We choose the Internet café that had the most customers (and ADSL) as our main study site. An additional five interview participants were selected using a hallway selection policy on our visits to the Internet café (I1, I2, I3, I4, I5). The participants are random people who pass by in the Internet cafes (approx. age 20 – 35). Some customers at the café never used computers and relied on the manager to help them find information instead. These customers were excluded from our interviews because we did not consider them the direct users of the Internet. We can safely assume that our participants have both the need use the Internet and access to computers at the Internet café.

Another five students (approx. age 14 – 18) participated in the focus groups, including two business students (B1, B2) in one group and three art students (A1, A2, A3) in another group. We selected them in the same way as the other students, but they were given a laptop as a group and asked them to do whatever they wanted on a browser for us to observe rather than simply interview. The participants selected for the same group happened to be friends. Rather than impose artificial rules on their interaction, we allowed them to interact with each other naturally during the focus group. After 30 minutes, the participants were interviewed in groups and asked to reflect on their browsing activities.

At each of the sites we asked our interviewees to discuss their experiences with and usage of technology. We asked about the places where they used computers, the Internet, and ICTs in general. We also discussed prevailing opinions about ICTs and about their learning and use in relation to their occupation. Our interviews lasted between 15 and 30 minutes and were conducted in English (the official language of Ghana).

3.3 Findings

Common themes found in our observations and interviews include problems faced by Internet users in poor connectivity areas, as well as tactics users employed to deal with the slow connections. These findings come from subjective observations by the researchers as well as comments from the participants themselves.

3.1.1 Variance in Internet Connectivity

Both schools lack Internet connections because, according to the school principal, the Internet is not affordable. Many of the participants expressed concerns about the cost and availability of Internet connectivity.

> "Modem speed is slow, especially when it rains" – F

> "It is easier to get Internet connection today. My brother has a modem. But only people with nice jobs can get them." -N

Participants C and N both said that the most common types of Internet connections people use in Ghana are via Internet modems and wireless USB adapters. Though the wireless signal we received at the center of the town is nearly 2Mbps, the signal at the edge of the town is reduced to 15-50Kbps. During our four afternoon visits to the most popular Internet café, the ADSL modem connection was always less than the advertised 256Kbps per second and was disconnected on one day out of the four. The subjective opinion about network quality is highly consistent with previous investigations on Internet use in developing countries despite some of these previous studies being from over six years earlier [3, 8, 16].

3.1.2 Experts Cope with Slow Internet by Multitasking

The participants we observed in the Internet café sometimes opened multiple windows or tabs on their browsers. They sometimes also switched to offline applications to watch movies or edit documents while waiting for web content to be loaded. Because the average time for a page to be completely loaded is typically around a minute or more, this was a good way for them to make the waiting time more tolerable. However, we found that, as with previous studies in similar contexts, this tactic is only employed by experienced users [2, 8]. In contrast, during the focus groups where participants were students who had relatively low computer literacy, such behavior was not observed. Participants waited until the result page was fully loaded when searching and browsing, looked at the content on the page, and decided whether to enter a search query or click a link.

3.1.3 High Enthusiasm and Varying Computer Literacy

We found that, in general, people in Hohoe have limited knowledge of and ability to use computers and the Internet, but many people who did not have knowledge of computers expressed enthusiasm and interest in learning about using them.

> "Can you teach me how to use software?" - A1, A2, F

> "I hope you can teach the students and teachers how to use it." – School principal

This finding corroborates with previous observations regarding the high aspirations of the poor with regards to educating their children especially in relation to PCs [20, 26].

Other users who we considered experts were surprisingly savvy in their own way. These included one student with a computer at home and some of the ICT teachers.

All of the participants we observed needed to look at the keyboard when they typed and paused frequently when using computers. Also, when asked to type search terms such as their names several errors would be made.

Depending on the user, sometimes spelling errors were corrected, but many users did not correct spelling mistakes until they failed to make progress. At first we thought that this was due to low literacy or simply negligence, but we found that the experienced users would allow the search engine to auto-suggest corrections that they would then click on. We observed one user who simply entered the misspelled search query and relied on the incorrectly spelled search query returning suggested search results. They then decided whether to click on one of the links returned by the misspelled query or a suggested query.

3.1.4 Community Learning

Out of eleven participants, six mentioned using computers at home, seven at Internet cafés, and five at school. But all participants who had computers at home also visit either the computer labs at school or Internet cafés. Thus, these public locations are important spaces for people to use and learn computers and the Internet when it is available.

Students in Hohoe usually first learn how to use computers at school, from their teachers and from each other. At the Internet café, the Internet manager usually plays a role in teaching customers how to use computers and the Internet. In the classes and focus groups we often observed students learning by looking at and mimicking each other. Students also discussed problems using the browser or an application with each other. The person who was the best at using computers in the group usually showed the others how to do different tasks.

3.1.5 ICTs as Foreign Languages and Abstract Concepts

It is worth noting that the idea of foreigners conjured utopian images of wealth and modern life in the minds of Hohoe locals. We observed that ICT was often treated as a foreign technology rather than a tool that people felt dominion over.

In the ICT classes we observed, students were instructed to follow exactly what the teachers ask them to do. They were not encouraged to explore the system by themselves nor do they try to do so. Most of the time, students took notes of terminology and vocabulary, such as "active cell", "formula bar", etc. We observed that teaching mechanical competence via rote learning dominated over generalizable understanding. Teachers asked questions like "What are the buttons on toolbars in MS Word". During the interviews afterward, we found that people use the exact wording to refer to the same interface components. This may have been caused by some participants language skills, but we discovered that students considered themselves incapable of using an application without learning it formally first, specifically, by being taught the names and concepts.

Furthermore, most participants had an idealized interpretation of ICT, which is a term that repeatedly appeared in our conversations with people in Hohoe.

> "I spend a lot of time on ICT." - F

> "If I tell my mom I'm going to the Internet café today, she will be very happy for me because I am learning something about ICT." – N

We hypothesize that this idealization may be linked to the way ICTs are introduced and then subsequently taught. As ICTs become more familiar this idealization may dissipate.

4. DESIGN OF TROTRO

To deal with the challenges described in related work and user study, we designed a web browsing system, TroTro, which detects Internet connectivity quality and adapts the set of active optimizations and user interface elements to maximize interactivity and quality of service.

We incorporated as many of the findings from our user study as we could, but chose to focus on enabling a consistent web browsing experience because that seemed to be one of the fundamental problems. In contrast, the asynchrony of email makes it an easier problem to solve as it requires few changes to operate in poor network settings. Similarly, the behavior of instant messages degenerates to email in the worst case: messages are either delivered in real time if the connection is sufficient or queued for delivery. Facebook and other active websites are a more demanding subset of general web browsing that will require additional engineering to make usable. As with many of the other potential improvements suggested by our study we leave social networking sites as a topic for future work.

TroTro borrows from and extends ideas from several previous systems designed specifically for offline web [6], intermittent web [7, 21, 23], and low-bandwidth browsing [15, 16]. TroTro uses a model of web information retrieval that interposes a web proxy between the web servers on the Internet and local clients' web browser to mediate the user experience over the underlying (dis-) connection. A simple diagram of the system is illustrated in Figure 1. The figure shows the proxy collecting web requests from the users and retrieving the content from the Internet and aggregating it for future use. Our system was implemented on top of an existing open source intermittent web browser, RuralCafe [7] (written in C#). We implemented our custom interface using HTML, Javascript, and CSS with supporting hooks in RuralCafe to support the additional functionalities of real-time queue management, live search, content clustering, and login elements.

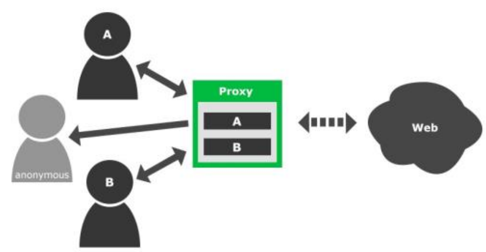

Figure 1. Diagram of TroTro architecture.

4.1 Deliver Web Content across Different Internet Connectivity

TroTro consists of many system optimizations that intend to provide the highest quality of service for three distinct network conditions (or operating *modes*): "online", "slow", and "offline". Certain features such as aggressive web page caching and notification of connection state are always on, while other situational features such as cache search and queued page downloads are only available in specific modes. TroTro's user interface maintains a consistent look and feel across these disparate network conditions and during transitions between them.

One central function of TroTro is the delivery of web content from a local cache and the Internet appropriately. Web requests are handled normally when there is a good Internet connection ("online" mode). When there is slow or no Internet connection ("slow" and "offline" modes), TroTro queues the requests sent to the Internet, retrieves them when there is a sufficient connection, and stores them in a local cache. Users can browse and search for pages in the local cache when there is slow or no Internet connection.

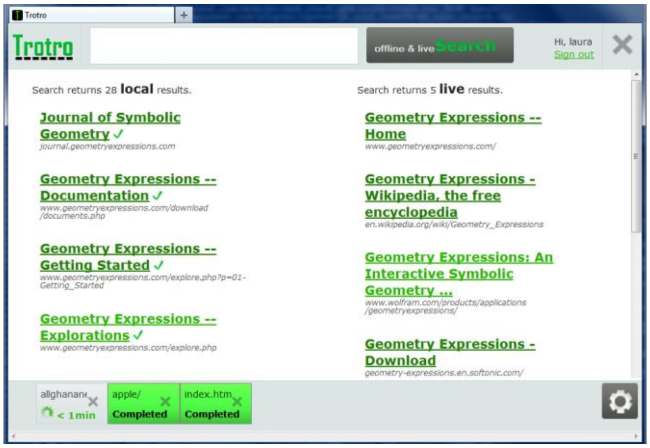

Figure 2. Screenshot of search result page in the "slow" operating mode.

When the Internet connection is in the "slow" mode, all content in the cache and on the Internet is searchable and accessible. When the Internet connection is good ("online" mode), TroTro delivers web content transparently. In general, the different modes store, retrieve, and search using either the cache, the Internet, or both, so that web content are always available to users regardless of the Internet connection. Figure 2 is a screenshot of the "slow" mode search results page. The column of "offline" mode results (left) and "online" mode results (right) are combined together in the "slow" mode results. In "offline" and "online" modes only the results from the left or right column respectively is present. The status of the system is made visible on the search button.

4.2 Improve Individual's Search and Browsing Experience

Our participants' low computer literacy and rote learning of ICT are strong indications of their frustrations with Internet use. Ackerman argues that there is always a social-technical gap between the social needs and the technologies available [1]. Rather than trying to close the gap, we should try to find the solutions within the ways people are already using the technologies (i.e. the tactics employed by users usually are the most affordable and efficient design solutions[1]). We can leverage some user strategies observed in our study to design intuitive and fluent interactions. Opening multiple windows or tabs during browsing and searching has been used by experienced web users to benefit backtracking and multitasking [2]. If these kinds of implicit multitasking activities were transferred into explicit user-system interactions, we could make the browsing experience more efficient. Auto-correct and auto-suggest should also be available at all times to help with typing errors and assist in the discovery of intended topics.

Allowing logged in users to queue requests encourages multiple simultaneous page requests and allows users to keep searching for new websites while waiting for others to load. The queue is both a record of submitted requests and a tool for users to arrange browsing activities more efficiently. The requests for web pages submitted by a user during slow or no connection ("slow" and "offline" modes) are kept in the queue and visualized as clickables in all pages. They can be canceled by users to conserve network resources. The queue attempts to reduce the frustration caused by long loading times by making the loading status and estimated delivery time visible and explicit. Furthermore, the requests are provided on the screen in a non-intrusive manner to allow the users to continue adding other requests. When a link is visited and not available instantly, the queue informs the user about how the web request is handled under the current network conditions and what actions are available. This design is akin to a download manager for webpages, except that it is available in slow/no connection scenarios where we believe visibility and controllability of the loading process are most vital.

There should also be a balance between the novelty and the external consistency of our interface design. External consistency is a well-known heuristic that encourages interaction design to follow conventions formed by other similar tools or systems [19]. Because interactions appear to be more natural and direct when they are performed more frequently, a tool is easier to use if it is consistent with other tools. Thus it is beneficial for our system to remain consistent with other systems that support the searching and browsing tasks, namely browsers and search engines. In contrast, our system should distinguish itself from these other systems in the interaction design of new functionality and behaviors. For example, our system should have a special interface to convey how it handles web requests differently in different network conditions.

4.3 Serve the Information Based on Community Interests

Based on the user study, it would be ideal to design a solution that is community-based and community-driven because many web users in poor connectivity areas access the Internet in community spaces.

The web content in the cache is not only available to the person who requested the content, but also shared by people accessing the same proxy. This allows TroTro to be a community based search tool that caches the information that serve the interest of specific groups of people. Because TroTro contains a web interface that is supported by major web browsers, users can access the cached content from any computer that is connected to the proxy. An index page lists all the topics in the cache which is automatically generated by TroTro, giving users a sense of what is instantly available (Figure 4). Browsing and indexing can serve as an alternative to searching to minimize keyboard interactions in the process of finding websites. It is possible to categorize the websites in the system cache so that users can locate the ones they are looking for without typing keywords since keyboard interactions are difficult for people who do not have the benefit of years of familiarity with computers.

If a teacher uses a computer that is connected to a TroTro proxy to search for a class, all the students that have their computers connected to the proxy will be able to access the same information without an Internet connection. Thus, TroTro reduces both the time and bandwidth to transfer web content by capitalizing on the fact that within a community search interests are often similar [15]. Since the community trending topics are displayed by the TroTro index page, it is possible that individual choice is stifled by the interface. We hope to support a setting that allows users to

[1] Donner's study on beeping phenomenon in sub-Saharan Africa [11] and Burrell's observation on West African Internet scams [4] are both examples of this.

switch between community trending topics and individual trending topics in the future, but this is beyond the current scope of our work. Search is always an option for exploration beyond community topics as a fallback if this becomes an issue.

A user account is required to submit requests to be downloaded to prevent abuse of network resources, but all cached and Internet content is searchable and browsing cached content is possible anonymously. Privacy might be a concern arises with a shared community cache that is available for all users to browse. Thus, users should be able to turn off the indexing of their cached pages (but not caching itself) in the settings. This could work similar to the "incognito mode" in Google Chrome.

5. PROTOTYPES

Based on our function and interaction design, we developed a functional prototype of TroTro. We then conducted usability testing of TroTro at the two schools and Internet café where we performed our user research. Features designed for users typically without an Internet connection were emphasized at the school sites and a complete prototype was tested at the Internet café. We did not use the same prototype for each test iteration because our goal was practical design research. Instead, our interface was improved as usability issues were discovered. We briefly describe the main interface components and their evolution in our prototypes.

5.1 Index Page

TroTro has an index page designed to give users a sense of what is instantly available in the cache. This index lists the popular categories and sub-categories of websites that are stored in the proxy's cache. When users click on any category or sub-category, the search results for that topic will be shown. In our first prototype sample websites were included on this page, and when users clicked on a category, the category would expand to show the sub-categories and example websites for each sub-category (Figure 3, area b). Since this was rarely used, we removed the sample websites from the index page to reduce the clutter in the second prototype (Figure 4, area b).

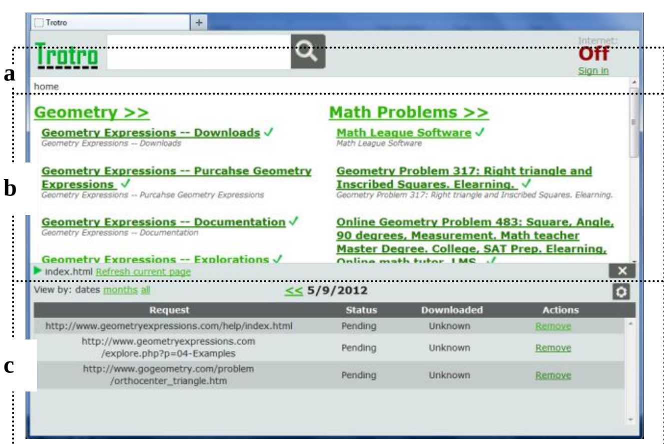

Figure 3. Prototype 1 - search box, index page, and queue.

5.2 System Status Display and Search Box

TroTro displays the system mode or status to users because search results and loading behavior of websites are different in different system modes. In our first prototype the system status display was

Figure 4. Prototype 2 - index page without having signed in.

on the top right corner, and in an intermediate version it was moved to the left right corner to increase visibility. A standard search box is located at the top left corner since it is one of most important functions of our tool and a magnifier was used for the search button, but participants found it hard to understand (Figure 3, area a). Our second prototype combined the status display with the search box button to clearly indicate both the system status and the kind of search that will be performed when clicked because this location appeared to be the most noticeable (Figure 4, area a).

5.3 Download Queue

TroTro presents a queue of web requests submitted to the proxy by a user. When the Internet is good, the queue disappears as requests queued during slow periods are fulfilled. The first design was a vertically scrollable table of the requests at the bottom of the interface (Figure 3, area c). The columns of the table were: the status of the requests, estimated time of arrival (ETA), estimated size of the website and links to remove the requests. When a link to an unvisited page was visited the request was added to the table if the Internet connection was poor. In our second prototype, we used a different design resembling a taskbar (Figure 5). Requests are displayed as buttons listed on a bar at the bottom, with status,

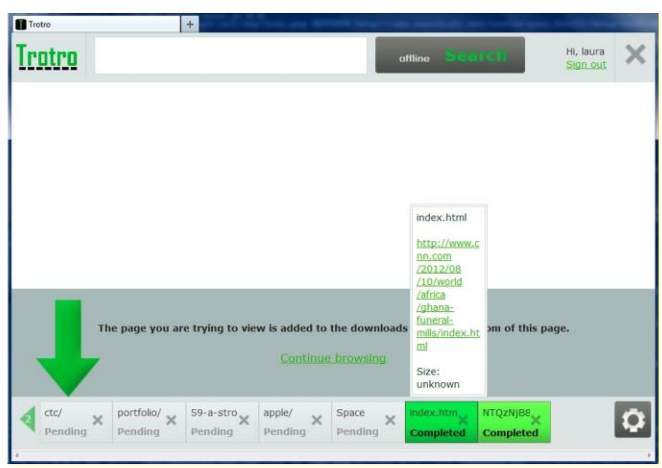

Figure 5. Prototype 2 - search box, message box, and queue.

Table 1. Summary of our usability testing results of both prototype implementations.

Use Case Number	Use Case of Interface Component	Prototype 1 Implementation (Both Schools)	Task Number	Use	Understand	Prototype 2 Implementation (Internet Café)	Task Number	Use	Understand
1	Visit topics in the cache from the index page	Topics with example pages	A1 A2	6/6	6/6	Topics only	B1 B2	2/2	2/2
2	Search for topics while online or offline	Icon on search button, separate status display, local search result page	A1 A2	2/6	3/6	Text and status display on search button, local and live search result page	B1 B2	6/8	8/8
3	Login and view requests	Login page	A2	4/4	3/4	Login page	B1	6/6	6/6
4	Add new request to the queue by clicking on an unvisited link	A table of requests, no redirect page	A2	1/4	2/4	A "taskbar" of requests, redirect page with a message box	B1	6/6	4/6
5	Download requests submitted offline when going online	N/A				ETA, request status, distinct buttons for completed items	B2	4/4	4/4
6	Distinguish live from cached content	Icons for cached content	A3	4/6	0/6	Local and live search results in separate columns	B2 B4	8/8	8/8
7	Manage requests in the queue	A table of requests, textual buttons	A4	3/6	3/6	A bar of requests, image buttons	B3	5/6	6/6
8	Download multiple pages simultaneously	N/A				A queue of requests, a message box	B4	4/6	4/6

ETA[2] and a close button on each of them. After a request is completely loaded, the button turns a high contrast color to show that it is clickable. Navigation to extra requests is controlled by a left arrow button and a right arrow button instead of the old vertical scroll bar because we found it more intuitive for novices.

6. USABILITY TESTING

We tested TroTro in several real settings to illustrate its practical usefulness and also to find any interface issues. Our goal was to measure the system's capacity to meet its designed purpose. People who have only used computers several times before face tremendous challenges when tasked with finding useful information online. Further, in slow and offline mode our system uses a cache metaphor instead of a standard "click and visit" metaphor. Before jumping in measuring the click-through rates in fluctuated connections, we felt that it was more important to evaluate whether the interaction design of our system is actually usable by people with close-to-zero computer literacy.

[2] The ETA is calculated using an exponential moving average which may not be perfectly accurate in a flaky network setting, but this is outside the scope of this work.

6.1 Methodology

We conducted our usability testing in the same Internet café and two schools as our user study. Computers from the sites were used for testing to preserve the original environment as much as possible. Three test participants were recruited at each school, and six at the Internet café totaling 12 participants. There were seven expert computer users: those who used computers for more than three hours per week, and five novice computer users. All participants were required to have enough basic computer skills to use a mouse and keyboard. Two participants were female. The test sessions lasted approximately 30 minutes. Each participant was given four tasks, asked to complete the tasks individually, and encouraged to think aloud. We screen recorded the sessions and took notes to document the usability tests. Testing for the first and second versions of the prototype consisted of different tasks. Examples of tasks include:

> "Suppose you want to learn about 'Parallelogram with Squares Theorem'. Please go to a related website." - task A1

> "There is a page you tried to view that does not exist. Please find it and remove it." - task B3

A task is considered completed successfully if participants clicked on the correct page elements on the interface or those on the testing websites within a few minutes. Though actual websites were cached and delivered to the user, we did not test navigation on live websites. A question was asked after each task to determine whether the user could understand the effect of their action. Our tasks and questions were to verify whether users understood and were able to use each interface component without any assistance. We conducted post-test interviews to gather comments about each participant's experience.

6.2 Results

It is possible for some tasks to be completed using alternative approaches than the interface components our tasks were intended to test and some tasks may require the use of multiple interface components. We counted the number of completed tasks that used each specific component. Since the main functionalities were sometimes implemented as different page components in the two prototypes, we also counted the number of completion for the two prototypes separately.

The results for components that are used in multiple tasks are aggregated. Participants' understanding of the use of the component was tested in the post-task interviews if no evidence of understanding was found in their think-aloud content. Sometimes, despite a participant finishing a task successfully by clicking on the correct page elements, the participants were confused by the system's response. We therefore also count the success rates for understanding the effect of their actions on each component. Our main results are summarized in Table 1.

In general, we found that with the first prototype the most common reasons for failures were due to visibility. Specific issues included: failure to locate or notice the search box, the table of requests, the link added to the queue, the icons for cached content, and the textual buttons. This was especially true for novice computer users. Some participants were also confused by the browser not navigating to the links they requested but instead adding them to the queue for later retrieval. Moreover, the table of requests frustrated participants because it was difficult for them to interpret as a queue rather than just a table. Also, we observed that none of the participants during the user study or during the usability test dragged the scroll bar; instead, they all used the arrow buttons. Thus, as described earlier, these page elements were redesigned in the second prototype.

In the second iteration of testing, we found very few usability issues. The two cases where searching for terms online and offline are failed are both due to misspelling of search terms. One participant was confused when adding a new request to the queue in task B1 because he did not see requests at the bottom of the page. Another participant was confused because he thought requests could not be sent when system is offline. The person who could not manage the requests in the queue tried to find the options in the right click menu. There were also two participants who loaded a new page after the first one was rather than multiple pages simultaneously.

6.2.1 Deliver Content across Different Levels of Connectivity

Our tasks were designed to measure whether users could use the different interface components across varying levels of Internet connectivity.

One measure we used was whether the system status was delivered to users. One of the biggest problems with the first prototype was that participants generally did not notice status display on the interface, including the network status, the caching status of search results, and the status of added requests. This problem was worst among novice users who report only seeing a small portion of the interface and whose task completion rates are much lower than experienced users. Thus, we reduced the number of elements on the page, increased the contrast of the status display, and only presented the critical interface elements on the front page. We verified that this issue was fixed by including the second task in the first iteration (task A2) of testing in the second iteration of testing (task B1).

Since the search results and caching behavior of TroTro is different in different modes, another measure for testing usability across different connectivity levels is whether the transitions among different modes are understandable and usable to users. We found that all participants were able to download requests submitted offline when the connection was re-established and distinguish live from cached content. The only case where participants were confused by the system response was when they used the system for the first time in offline mode. One participant said, "When you search offline you shouldn't see anything". Even participants who managed to perform searching and browsing in the offline mode did not expect the system to give any search results when they first used it. However, they were satisfied after they started seeing the results because "even though the network is down, we will be able to do something." When the system started to cache web requests and return live search results, all participants recognized that the system was loading the page. We found that these interactions were simple and intuitive for both novice and experienced users.

6.2.2 Improved Individual Search and Browsing Experience

Our usability testing checked whether participants were able use the queue, and further, used the queue to multitask. Given the tasks to delete a failed request from the queue (task B3), all but one completed the task without difficulties. When the six participants were asked to visit two webpages, four loaded two pages simultaneously despite being relatively inexperienced computer users. Because participants remained on the TroTro interface after a page was added to the queue, they tended to continue searching and browsing. All participants understood the display of the ETA of requests. Moreover, we found that the format of queue itself was able to inform users that some pages are not available yet and waiting is expected. One participant specifically pointed to the fact that he "can open multiple websites" as a reason for liking the system.

The browsing experience is further augmented with system messages and alerts shown when new requests are added (Figure 5). These messages explain that requests are handled in a certain way because of the network status along with a link to the index page. During the second iteration of testing, participants sometimes read the messages from the message box to try to understand why requests are not loaded in the browser immediately. One participant particularly liked the message because it "guides you on what to do next". The requests in the queue were referred by our participants as a "series of downloads", or simply "websites", which showed their understanding that the content was being queued.

6.2.3 *Exploring Community Content*

The prototypes we tested at different sites had different community-based web content preloaded onto their caches. Therefore, different topics were shown on the index page. The school sites were manually given topics around geometry and educational software. The Internet cafe was provided with latest news about Olympics and the late Ghanaian president, which were two popular topics at the time of testing. In the future, the actual topics may be generated automatically using information retrieval techniques [6]. No introduction to TroTro was given before usability testing. Nonetheless, when the participants were asked for the first impression of TroTro at the beginning of the test, all of them recognized it as a website with available topics on the index page. Two of the experienced computer users also recognized it as a search engine. We surmise that TroTro was able to give users a sense of what is available in the community's cache and therefore allow exploration.

7. DISCUSSION

In the process of designing and testing TroTro, we found several specific usability requirements that were unique to designing web tools for poor connectivity contexts. It is interesting, however, that despite the potential issues found in our user study (e.g. low computer literacy and foreignness of technology) and the introduction of novel functionality, we were able to achieve a high level of usability after relatively small changes in the interface design. We found that many of the general usability heuristics for the web were applicable.

The usability testing of the second prototype generated better results than the first in part because we increased the visibility of the major interface components, namely the queue and the search box. Since many of the individuals in our context were novice users we increased visibility also by limiting the number of options and actions available and added detailed descriptions when necessary. This approach was validated by our usability results, which tested first-time use of our tool.

Transparency is another user conceived property of interactive tools [10]. Changes in network states and request loading states are visualized and delivered to users in TroTro so that they are more transparent to users. This helps users plan for their future interactions. For example, knowing that the network is currently slow, a user could decide whether they want to visit a dynamic page that will be cached in a static manner for future perusal. In this case, a users' ability to accomplish a task is made possible by both awareness of the system operating mode and knowledge of system behavior in that operating mode.

Users with low computer literacy also need to be presented with a sense of directness. The main merit of the interaction design of the second prototype over the first prototype is that it gives users a more closely coupled relationship between an action they perform and the effect it produces. This is provided both by a short distance between the user goal and the interaction allowed by the system, and a sense of engagement provided by an interaction model that represents the real world [14]. When users want to visit a webpage, their intention is handled by the system checking the network connectivity and informing users on how the new request will be handled. Difficulties for users translating their intention into manipulations of page elements and for them to understand the system responses were both measured in the usability testing. We found that users had little difficulty with the second prototype.

Furthermore, a sense of engagement is provided by the queue metaphor used in the interactions. When websites are being cached, users should feel like they are directly adding the webpages into the queue. When websites have been loaded, users should feel like they are ready in the queue. The table used in the first prototype did not convey the queue metaphor as well as the bar in the second prototype. When requests were visualized as boxes with labels lined up on a bar, the interactions expected by the users naturally become adding boxes, deleting boxes, inspecting boxes, loading boxes, and opening boxes. This was easily related to adding requests, deleting requests, pointing at requests, waiting for the requests to be loaded and visiting the requests. In other words, these elements in the queue provided the action possibilities, or affordances that were natural to users. In contrast, the first prototype's items in a table did not seem interactive and thus did not provide the same level of engagement. Though the sense of directness is at the cost of number of actions available and number of items shown, it increases the ease of use. We found that the users who had little experience with web interfaces especially benefited from this kind of design. It is interesting that our final design is reminiscent of a download manager and perhaps a direction for future work is to simply extend the download manager metaphor within the browser to support searching and organization.

Learning and support also needs to be included in the interaction design. After the second prototype was tested, we left a copy of the system at the two schools and trained the computer teachers about how to use TroTro. Cached content is currently transferred from one computer to another manually. We will implement a more user-friendly version of this feature in the future so that users without too much knowledge of computers can learn how to use it. According to Lev Vygotsky, learning occurs in the Zone of Proximal Development (ZPD), which is the distance between an individual's ability to perform a task under guidance and/or with peer collaboration and the individual's ability solving the problem independently [25]. TroTro provides features that fall into the ZPD, allowing users to access web resources that are cached by their peers or guides. Our platform can be further extended to function as a collaborative system for organizing information and community learning.

In all test sessions, test participants had no problems signing in to retrieve the requests submitted before. This raises the concern of whether the users are aware of the privacy issues. They did not have questions about whether the requests submitted by them can be viewed, used and changed by third parties. This is likely due to their idealized image of Internet technologies. We plan to evaluate the real-world usage of the system in the future. We chose to discuss usability heuristics for systems in low connectivity areas in this paper because this is the most demanding problem we found throughout our study.

8. CONCLUSION

We found in our study that beyond the numerous technical and economic barriers there are also significant usability issues that prevent Internet use especially by novices in rural areas. We designed and evaluated a web browsing tool to lower these other barriers by following standard web usability heuristics in combination with context-specific considerations. Our system, TroTro, allowed users to interact comfortably with the web despite unpredictable fluctuations in network quality. TroTro enriched the interaction experience for individual users while lowering the bar for novices learning how to use the Internet and give them transferable experience. We hope that systems like TroTro can lead to increased adoption of Internet technologies in places where, currently, training for each new ICT intervention is like learning a new foreign language.

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