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Real-time Analysis of Time-based Usability and Accessibility for Human Mobile-Web Interactions in the Ubiquitous Internet

Yung Bok Kim
(Sejong University, Seoul, Korea
yungbkim@sejong.ac.kr)

Abstract: In the ubiquitous Internet, human mobile-web interactions can be evaluated with real-time analysis of time-based usability and accessibility with the different types of mobile Internet devices including smart phones (e.g. iPhone, Android phone, etc.). A ubiquitous mobile-web interaction server, accessible with a variety of mobile Internet devices, could be a unified estimation hub in real-time analysis of human-centric mobile-web interactions. We propose the real-time analysis scheme based on real-time estimation of time-based usability and accessibility for human mobile-web interactions with a name-based directory server for social networking in the ubiquitous Internet environment. We present an implementation of a ubiquitous mobile-web directory service and discuss our approach with some empirical results.

Keywords: Mobile-web, Interaction, Time-based Usability/Accessibility, Ubiquitous, SNS
Categories: H.3.1, H.3.3, H.5.2

1 Introduction

The Human-Computer Interaction (HCI) field and all its concerning research areas are constantly changing and evolving to achieve a better perception of computer systems in general from the end-user's point of view [Lozano, 08]. Mobile devices such as smart phones are changing end-users' web interaction activities because of easy connectivity to the ubiquitous Internet. We have researched human-centric mobile-web interactions and simplified the real-time analysis scheme in an environment flooding with information, especially in the ubiquitous Internet environment.

The user interface is a crucial aspect for the successful usability of mobile applications, since it facilitates communication, collaboration and coordination activities between several users interacting with web-based systems. The user interface should support the interaction between a user and the system so that individual tasks can be carried out, as well as the interaction between users through the system so that they can get involved in common tasks and enable social interaction between the members of a group [Penichet, 08].

We studied a social community portal service with convenient accessibility for social networking including the disabled and the elderly in the aged society [Kim, 06], but mainly with the wired Internet. In the ubiquitous Internet, using mobile Internet devices, we present a human *mobile-web* information service with a ubiquitous name-based directory server for efficient interaction as well as for the integrity of consistent information in social networking. Social networking involves mapping knowledge flows and gaps to identify and maximize connections [Liebowitz, 10]. Mobile social networking with *Twitter* and *Facebook* using smart phones (e.g. iPhone, Android phone, etc.) has been proliferating rapidly all over the world.

The mobile-web server with a ubiquitous name-based directory (accessible ubiquitously with any Internet-capable device at anytime and anywhere) can be a hub in human mobile-web interactions for a ubiquitous mobile-web information service and real-time mobile-web interaction analysis. The client mobile devices (e.g. iPhone, Android phone, etc.) for mobile-web information access have become very important for human mobile-web interactions in the ubiquitous Internet environment.

The W3C Web Content Accessibility Guidelines (WCAG) are general principles for making web-contents more accessible and usable for people with disabilities [Leporini, 10]. A relatively large set of metrics have been introduced in the usability and accessibility literature, however we considered the *time-based accessibility* based on the time metric, instead of *web-contents accessibility*, for real-time estimation and comparison among different services for any mobile-web users.

We present the *time-based usability and accessibility* of human-centric *mobile-web interactions* for ubiquitous web information services, using a ubiquitous mobile-web directory server and mobile Internet devices for many user/group profiles (e.g. SNS user, lecture-group, alumni community, etc.), with a real-time estimation approach. We chose the unified/simplified *time-metric* for comparison among even different types of services. Including real-time estimation of *time-based usability*, we researched the *time-based accessibility* in real-time estimation using a common time metric. We propose the human-centric *time-based usability and accessibility* for real-time quantitative estimation with synthetic approach instead of analysis with various qualitative factors, considering relative mobile-web interactions among various daily human activities.

We implemented a simplified and unified portal with a ubiquitous name-based directory for social networking by mobile devices such as smart phones (e.g. iPhone, Android phone, etc.). Instead of a qualitative approach, we used quantitative time-metric for *time-based usability and accessibility* for *real-time estimation* and applications in the ubiquitous Internet environment. Instead of download-based mobile applications in the *iPhone App Store*, we researched *mobile-web service* based on web standards such as *HTML4, JavaScript, and XML* (including emerging *HTML5* in near future); the mobile-web service may dominate after a couple of years rather than download-based applications from the *App Store* service.

In the following sections, we introduce background with related works; here we introduce and discuss (*time-based*) usability and accessibility with distinctive approach, real-time information search, and name-based search and multilingual domain names, especially considering human (i.e. I-centric) mobile-web interactions from the mobile-web user's perspective. Next, we present a real-time analysis of time-based usability and accessibility as real-time stochastic parameters (random variables); here we present human mobile-web interactions and present real-time estimation/analysis schemes. Then, we present an implementation of a ubiquitous mobile-web name-based directory service for mobile social networking, and we discuss mobile-web interactions as well as time-based usability and accessibility with empirical results and some experiences in social networking. We also discuss an application for offline analysis with the limitation of our approach. Finally, we conclude our study with consideration of future work.

2 Background and Related Works

For real-time analysis for human mobile-web interactions, we researched background and related works: usability and accessibility, real-time information search with mobile Internet device, and mobile-web name-based search as well as multilingual domain names as an example for world-wide domestic mobile-web users.

2.1 Usability and Accessibility

Usability and Accessibility (U&A) guidelines have been set up to help designers in the process of creating usable and accessible sites [Liu, 04]. One of the most proactive initiatives is the Web Accessibility Initiative (WAI) that was set up by the World Wide Web Consortium. This initiative published the well-known Web Content Accessibility Guidelines (WCAG), which is the most universally accepted and established set of guidelines for developing and evaluating web content accessibility. Even though all these efforts are extremely useful for producing accessible web applications, they have proven insufficient in achieving the universal access objective. Unfortunately, many websites required to be accessible by law are still not accessible [Arrue, 08]. Actual usability and accessibility of web pages varies depending on the type of information the user is dealing with, and the guidelines are often loose and their successful application is too much dependent on personal interpretation [Leporini, 08].

The definition of *usability* for mobile devices was referred [Betiol, 05] from of ISO 9241-11: “The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use.” A system for automatically evaluating the usability and accessibility of web sites by checking their HTML code against guidelines has been studied by Beirekdar et al. [Beirekdar, 05]. The usability of mobile devices and their applications is a key factor for the success of mobile computing. Betiol and Cybis [Betiol, 05] studied usability evaluation of mobile interfaces. They mentioned the importance of the context in use of mobile devices in the usability evaluation, so that the traditional HCI evaluation criteria and methods should be reconsidered in order to meet the requirements of mobile interaction. There are now more browsers on mobile phones than on desktops, and there is a vast diversity in the types of devices. On top of this diversity, there is also the diversity required for accessibility [Pemberton, 05b]. The features of websites that we visit regularly, that differentiate them from websites that we do not visit; Forrester did some research on this as follows: good content (75%), *usability* (66%), speed (58%), frequency of updating (54%), (the rest is noise: 14% and lower) [Pemberton 05a]. This is in accord with Pemberton’s comment, “*device independence, accessibility and usability are surprisingly closely related.*” We assumed that there may be a time-related correlation between time-based usability and time-based accessibility in a ubiquitous mobile-web service, even though general usability and accessibility are two different quality characteristics.

A system with poor usability can cost time and effort, and can greatly determine the success or failure of a system; according to Palanque’s research [Palanque, 07], empirical usability evaluations, such as *formative* and *summative* evaluations are not sufficient when dealing with complex safety-critical interactive systems that have an extremely large number of system states. We considered the *summative* usability-evaluation instead of *formative* scheme, because we try to evaluate the mobile-web service, which is time-critical rather than safety-critical, in realistic service. For formative evaluation before real service, we may apply the Formal Description Techniques for development of mobile-web services.

Measuring the usability of a given context of use as a whole is a challenging problem, and providing an appropriate solution for such a problem can be extremely helpful for software development and usability engineering. Usability evaluators can rely on the usability features detected for a particular context of use as a whole when assessing a new interface belonging to it. The ultimate goal is to promote an adequate translation of international standards, methods and ideal values related to usability in order to adapt them to specific contexts of use [Gonzalez, 08].

The quality characteristics, usability and accessibility, are complex so they should be properly decomposed into many quality attributes and several metrics should be used for measuring them, usually on the basis of offline analysis for particular contexts of use. We focus on the *time-based usability/accessibility* (with time metric for simplicity, consistency and real-time estimation) instead of web-contents usability/accessibility, especially in real-time analysis for emerging real-time mobile-web applications (e.g. real-time SNS such as Twitter service). We used the time [second] metric for simplicity as a quantitative metric as well as a common metric for performance comparison of homogeneous or heterogeneous type of web-based services, competing by various service providers.

2.2 Real-time Information Search

Search engines (such as Google) are frequently used tools for people to find their needed information on the web using search keyword(s); however, the accuracy, speed and relevancy of their returned results are still not satisfied in many cases, and search engines usually return a number of links of web documents but still cannot guarantee the relevancy to the user's question [Wenyin, 08]. Some web sites, such as news information sites, are checked very often, but others await their turn in a rotating schedule of visits by each crawler. For time-critical applications (e.g. real-time registration and advertisements) at the user's viewpoint, it takes long time to register new information on a web site and be searchable by commercial portals (e.g. around 5 to 7 days or more by Google, around 6 hours to 1 day or more by Yahoo, over one week by other portals).

In searching with commercial engines, web users are utterly dependent upon their search tool. All pages change their rank at unpredictable times as search engines update their index and algorithms, which involves advanced mathematics. Calculating PageRank, or building the neighbourhood graph's connection matrix and analyzing it to determine communities, is not easy. Combining prestige and relevance, and optimizing the various factors involved, involves tedious experimentation with actual queries and painstaking evaluation of search results. Search engines are starting to acknowledge the importance of *personal interaction*; they are beginning to recognize communities too. Peer-to-peer technology will offer new perspectives in web search [Witten, 08]. We should consider real-time search in social networking as follows.

As an SNS, Twitter for real-time information network is the hottest social medium around; the micro-blogging application enables anyone with Internet access to issue short public messages [Reisner, 09]. Twitter's search service does not consistently deliver real-time results: 20 or more minutes (or hours/days frequently because of over capacity) often pass before a given tweet appears in search results [Stross 09]. Because of over capacity with rapidly increasing traffic in Twitter service, frequent failure of service has occurred. The real-time search and real-time service are becoming increasingly difficult to the point of impossible, especially in real-time search after tweeting. In our research, Twitter is not for the real-time (i.e. within deterministic time) information network. Keep tracking on twittering becomes more complex as the number of following people (in Twitter) increase with flooding of various and scattered (i.e. incohesive) information.

Pervasive systems augment environments by integrating information processing into everyday objects and activities. When a user makes a vocal request (e.g. Google Voice Search), a multimodal browser looks for a match in a local grammar file or from a cloud computing. If the browser finds a match, it submits the recognized query text to the reasoning module, where a chatbot attaches semantics to the text and builds the answer based on an ontology query. This user-centered operational mode improves the system's user-profiling capabilities while still maintaining its flexibility for group management [Joseph, 10].

With evolution of web-based technology and service, the performance of a web service (including search) as a service platform has become a central issue in providing a ubiquitous, reliable, and efficient information network. Especially mobile-web services are emerging as essential service in various areas (e.g. in social networking) with smart phones. *Real-time searching in the mobile-web with smart phone becomes more important, and we need more efficient scheme.* For multilingual users, we propose a better way for the real-time information registration and search. Considering usability and accessibility for multilingual users with smart phones in the ubiquitous Internet environment, we also propose a more efficient way to find mobile-web name cards, web-based phone numbers (of friends, relatives, or alumni), micro-blog URLs as well as SNS URLs instead of inconvenient favourite folders dedicated to a personal device.

2.3 Name-based Search and Multilingual Domain Names

The application of semantic wikis as knowledge engineering tool in a collaborative environment was considered by Nalepa [Nalepa, 10] as follows. Pages are identified by a unique keyword (name) and usually grouped within the so-called namespaces. Pages can be arranged into namespaces which act as a tree-like hierarchy similar to directory structure; wikis are composed of wiki pages; pages are usually grouped within namespaces related to their common semantics, which can be explicitly marked in the semantic wiki ontology.

For real-time information access users, even the input of a text-string search keyword (i.e. name-based) becomes important for the search of information or the registration of information with mobile phones, especially with keypads in the mobile phone for a text-string URL or a search keyword. To access the mobile-web name-based directory service ubiquitously, the user interface should be convenient even for typing-in the multilingual domain names, URLs, or general information. For writing a search keyword in real-time way, the user's typing speed of a text-string is an important performance factor, especially with mobile phones. More convenient keypad-stroke is required for the mobile phone user to access information with a keyword (i.e. name-based) using a ubiquitous name-based directory service. We considered the time-based usability and accessibility of human-centric mobile-web interaction with mobile phones as well as with PCs, especially using a name-based directory server accessible with many simple (single-character) multilingual domain names related to search keyword/name.

We researched to use TLDs (Top Level Domains) (e.g. converted ASCII Punycode format: 'http://xn--ypd.net', 'http://xn--4pd.net', 'http://xn--4k0b.net', etc. for a single-character multilingual language) related to the search keyword/name for multilingual users. We considered the syntactic structure for searching web-based information with time-based usability and accessibility by smart phones (e.g. iPhone and Android phone). The scheme for multilingual domain names has been standardized world-wide by IETF (Internet Engineering Task Force) and has been approved by ICANN (Internet Corporation for Assigned Names and Numbers). The auto-conversion functionality (i.e. from multilingual domain name to Punycode ASCII, or vice versa) for standardized multilingual domain name service has been embedded in the web/mobile-web browsers as a built-in functionality, e.g. from the recent version of MS IE and Firefox, Opera, Safari, Google Chrome, etc.

There are many SNSs, micro-blog services, mini Home Page services, Café services provided by many global/domestic service providers (e.g. global: Twitter, Facebook; domestic: Me2day, Yozm, etc.). We assume that any service provider cannot be a unified portal with the current SNS model. We propose the (I-centric) mobile-web name card in a unified-ubiquitous directory as a *personal portal* to initiate different SNSs, micro-blog services, mini Home Page services, which we (or I) manage in our (or my) mobile-web name card accessible with many single-character (e.g. multilingual alphabet) TLDs related to our (or my) name. *Figure 1* shows the I-centric mobile-web name card in mobile-web interactions for mobile SNSs such as Twitter with the iPhone or Android phone. We propose *a ubiquitous mobile-web name-based (e.g. name card) search with directory* for real-time applications such as real-time SNS.

Figure 1: I-centric Mobile-Web Name Card for Mobile-Web Interactions with iPhone

In an SNS such as Twitter and many other local/global social networking services, the performance and quality of experience (QoE [Fiedler, 10]) related to quality of service (QoS) are becoming more important, especially for real-time information networking with real-time registration and searching of human-centric (i.e. I-centric) name-based information for real-time SNS. We propose the time-based usability and accessibility as real-time QoE parameters as a further research issue.

3 Real-time Analysis of Time-based Usability and Accessibility

We considered a time-based *usability* and a time-based *accessibility*, and we focused on a quantitative time-metric instead of qualitative metrics. The *time-based usability and accessibility*, are stochastic random variables, and we estimate in real-time for real-time applications such as real-time social networking. We present mobile-web interactions in social mobile-web activity and real-time estimation/analysis scheme.

3.1 Mobile-Web Interactions

Jakob Nielsen [Nielsen, 05] mentioned that "accessibility is not enough; the accessibility fallacy is the assumption that accessibility exists in a vacuum and can be scored without considering users and their tasks. Usability's job is to research user behavior and find out what works. Usability explains human behavior in complex systems under strongly context-dependent circumstances. On average, websites that try usability double their sales or other desired business metrics." Nielsen studied various usability(e.g. web usability, intranet usability, application usability, email usability, agile usability, mobile usability, donation usability, WAP usability, investor relations usability, etc.). However a comparison between different types of usability may be very difficult, and they are not appropriate for real-time analysis. We believe that usability is extremely relative and stochastically changing and is being affected by other services/products because of the 24-hour time constraint in human activity. Instead of general usability, we focused on the real-time estimation of time-based *usability* with a common time-metric for comparison among different services.

We focused on the time-based usability and accessibility of mobile-web interaction with single-character multilingual domain names (e.g. converted ASCII Punycode format: 'http://xn--ypd.net', 'http://xn--4pd.net', 'http://xn--4k0b.net', etc.) as single-character keys in a unified-ubiquitous name-based directory for SNS, from the user's viewpoint. An activity (i.e. mobile-web search/publish in our discussion) is meaningful with actions [Kirlidog, 06], and actions are meaningful with operations; activities, actions, and operations are not static structures. We considered the activity (to publish and search specific information using mobile-web), actions (i.e. some sessions with mobile internet devices), and operations (e.g. real-time interactions as follows). We studied the time-based usability and accessibility in human-centric mobile-web interactions from the user's perspective. They are stochastic random variables, and we need to estimate them in real-time way for real-time applications (e.g. real-time comparison of large scale social mobile-web sites and real-time advertisement in mobile SNS, etc.). We analyzed the random variables with time metric, mainly the spent time by user and the input time on keypads for URL(s) or search keyword/name in the human mobile-web interactions.

For example, for a mobile user in *Figure 2*, we assume that a random variable, the accessing interaction time as a user's one-way interaction in a session, from a user to the contents in DB through the ubiquitous Internet before next backward interaction with a smart phone is $\mathbf{I_a}$. That is composed of the preparation time for any user in the ubiquitous Internet environment to get a mobile Internet device for interaction in his hand is $\mathbf{P}$. The time spent by the user with the mobile Internet device to make the appropriate interaction for service is $\mathbf{M}$. The aggregate interaction time to the web server after the mobile Internet device through the ubiquitous Internet for mobile-web service is **W**, and the network time is embedded here. The interaction time depending upon mobile-web contents is **C**. Therefore the operation time in a mobile-web activity is composed of **P, M, W, C**. We present the time-based usability and accessibility for human-centric mobile-web information services on the basis of the real-time estimation of the stochastic random variables: time-based usability and accessibility.

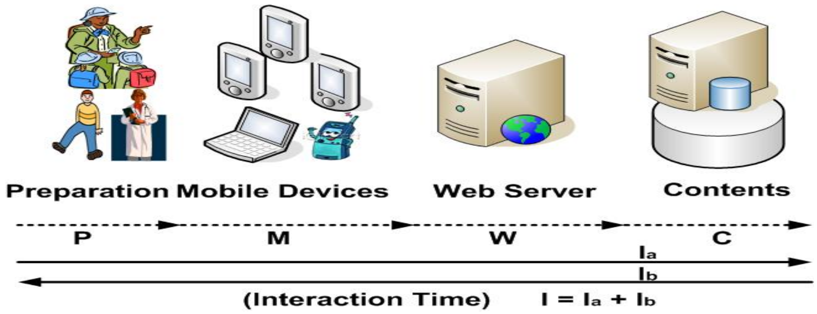

Figure 2: Interaction Time in a Session of Mobile-Web Interactions

The session time based on mobile-web interactions may be dependent on this content retrieval or registration, and there may be several back and forth iterations during the session. The returning backward trip time in the session, from the content retrieval time to the requesting user through web server and the ubiquitous Internet using mobile Internet device such as iPhone, is $\mathbf{I_b}$. A single interaction time **I** is the summation of $\mathbf{I_a}$ and $\mathbf{I_b}$. Of the above random variables, i.e. the performance parameters, (**P**, **M**, **W**, **C**) for mobile-web user, the most dominating factor, i.e. the random variable, may be different from user to user as well as from service to service. The previous works for computer networking have been mainly focused on the analysis of the random variable time, **W**, as well as other individual random variable times, but we suggest the average overall parameter for evaluation of a session, i.e. the single interaction time Mean(**I**), instead of the partial and minor delay **W**. The user preparation time for mobile-web interactions, Mean(**P**) will decrease depending upon the proliferation of smart phones in the ubiquitous Internet environment.

For the real-time application in the ubiquitous Internet, the dominating factor and the variance of that averaged random variable should be bound within the deterministic response time. We also considered the packet size to be independent from the network traffic conditions as well as the simple service in the web server to be immune to the load of the web server in ubiquitous mobile-web information services. As an example for multilingual applications, we can consider the average keypad-stroke number in the case of a mobile phone; this is related to the device time Mean(**M**). For writing the information in real-time way, the user's typing speed of search keyword composed of multilingual characters is one of the important performance factors in any mobile-web services with a smart phone. This is also a critical dominating factor related to the time, **M**, especially for writing contents (e.g. tweeting in Twitter) with a smart phone such as the iPhone or Android phone.

3.2 Real-time Estimation and Analysis

In the previous *Figure 2*, we showed a simple example with a single interaction. However there may be actually several mobile-web interactions in a session as shown in *Figure 3* below. We present the human-centric time-based *usability* and *accessibility* in mobile-web interaction service; a service must be *accessible* for the service to be *usable*. Time-based accessibility is presented on the basis of quantitative metric such as time [second]; usability has not been studied a great deal with a quantitative metric, as researchers tend instead toward some qualitative evaluation. We discuss the time-based *usability* based on the time-based *accessibility,* and then we discuss the human-centric time-based accessibility in a session. We used a fundamental time-metric [second] for simplification; the stochastic estimation of the random variables, i.e. the time-based *usability* and time-based *accessibility,* was studied on the basis of real-time time-series analysis at mobile-web directory server side instead of user side.

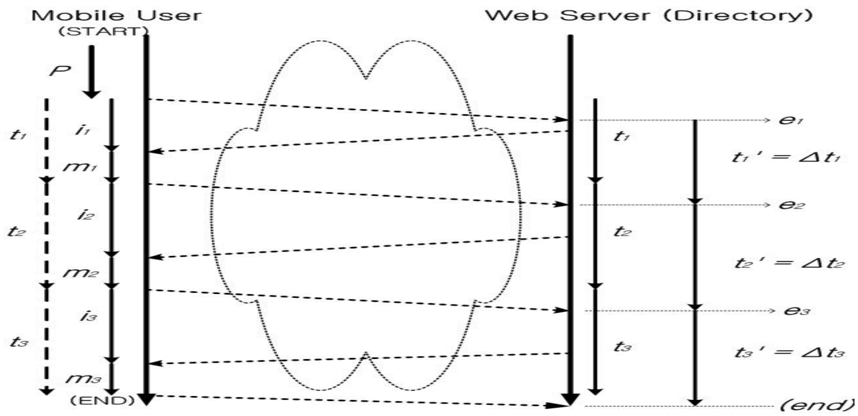

Figure 3: Human Mobile-Web Interactions in a Session

In *Figure 3*, the interval time between event $\boldsymbol{e_2}$ and event $\boldsymbol{e_1}$ is $\Delta t_1 = e_2(t) - e_1(t)$, which can be estimated in real-time with simple implementation at a mobile-web interaction server. Similarly, the interval time between event $\boldsymbol{e_3}$ and event $\boldsymbol{e_2}$ is $\Delta t_2 = e_3(t) - e_2(t)$. We can estimate stochastic statistics of random variables (i.e. t_1, t_2,…). The number of user interactions in a session can be estimated with the incoming events at the mobile-web interaction server. The number of total sessions by users or clients in a mobile-web site can be estimated with statistics for the estimation of time-based usability, as follows. The time-based *usability,* which should be estimated in real-time way as quantitative metrics (i.e. "how much usable is the mobile-web site per day?"), could be defined with the equation as follows:

$$Usability_t = \sum_{j=1}^{f} A_j \tag{1}$$

where f is the number of daily sessions by the same or different users, i.e. frequency per a day (or 24 hours); the subscript '$_t$' means 'time-based'. The f is random variable related to usage of a service (e.g. Google search, Twitter service, etc.) by a user, by a community, or by any group. $\boldsymbol{A_j}$ is the time-based accessibility in j_{th} session for mobile-web interactions in a day, therefore the time-based usability is the daily (or hourly, weekly, monthly, yearly as an interested period) summation of the accessibility, as follows:

$$Usability_t = \sum_{j=1}^{f} A_j \approx \overline{A} * \overline{f} \tag{2}$$

For simplicity in our discussion, the time-based (hourly, daily, weekly, monthly or yearly) *usability* as stochastic parameter could be approximated with the multiplication of the mean of time-based *accessibility* and the mean of (hourly, daily, weekly, monthly or yearly) usage frequency f. The smaller the value of time-based *accessibility* [second] for completion of a session is, the more accessible the mobile-web interaction service for a user/group is. The larger the value of time-based *usability* [second] is, the more usable the mobile-web interaction service for a user/group is (e.g. proliferating Twitter service).

For real-time estimation, the interval time between incoming events for i_{th} interaction in a session by a user (estimated at web directory server), t_i , then the overall interaction duration time for a j_{th} session in information access is $T_j = \sum_{i=1}^{n} t_i$, where n is the number of interactions (at user-side) or incoming events (at server-side) in a session. T, which is the total session time, is related to the time-based *accessibility* [second] (i.e. "how fast to complete a session"), for the mobile-web interaction in our discussion. *Completion time related to web-contents accessibility is embedded (in terms of time) in a session time.* For real-time estimation the session time could be estimated consistently on the basis of easy implementation in the programs (such as ASP, JSP, or PHP) running in the web server, instead of estimation at user-side.

$$Accessibility_t = T_j = \sum_{i=1}^{n} t_i = \sum_{i=1}^{n} t_i' = \sum_{i=1}^{n} \Delta t_i = A_j \ \textit{[second]} \tag{3}$$

For real-time interactions in the ubiquitous Internet, the dominating factor and the variance of that averaged random variable should be bound with the deterministic session time (i.e. the completion time of a session in a mobile-web server). To be deterministic in real-time mobile-web interactions, the mobile-web user should be skilled, the mobile-web user interface should be convenient, the network should be stable if possible, the mobile-web server should be efficient, have a high performance for the application and finally, the contents for a ubiquitous mobile-web information service should be as simple as possible with a simplified and efficient structure for mobile-web interactions. The bandwidth requirement for the ubiquitous Internet should be low in order to be immune to the network traffic conditions for real-time mobile-web interactions. In *Figure 3*, *P* is a preparation time for mobile-web interaction service; the time will be shortened in a ubiquitous Internet environment with smart phone such as the iPhone or Android phone.

With this concept, we can compare the *time-based usability* as a common time-metric among different types of services. For example, the *time-based usability* of Google service for a specific user/group as well as worldwide users/groups may be compared to the time-based usability of Twitter service for a specific user/group and worldwide users/groups, in a real-time way on the basis of a common time-metric. We found that the time-based usability and accessibility are not constant and they are stochastically changing random variables. The other services or activities are affecting the stochastic time-based usability, and new services or other activities will also affect the time-based usability of a specific user or user groups (e.g. various communities), as *Twitter* and *Facebook* services affect *Google* service and others, etc. For a more usable service, the time-based accessibility will become smaller, and the usage frequency of the service will be greater; *the time-based usability (i.e. the multiplication of time-based accessibility and usage frequency)* will increase.

The *time-based usability* and *time-based accessibility*, equation (1) and (3), as stochastic random variables, could be used for both offline analysis and real-time analysis. We studied the real-time estimation of statistics (e.g. $Usability_t$, $Accessibility_t$, f) as performance metadata stored in a mobile-web name-based directory server. For *real-time estimation*, we used an exponentially weighted moving average model with the appropriate smoothing parameter α to get the mean value of the random variable x_k , which may be related to any random variable among the discussed random variables (e.g. $Usability_t$, $Accessibility_t$, f). To discover the statistical outlier for eliminating from the real-time estimation of statistics, the deviation value can be used, as well as the mean absolute deviation (*MAD*) model to reduce the complexity of real-time estimation of stochastic random variables.

The random variable, time-based $Usability_t$**:** ***U***, required for real-time estimation can be estimated as follows:

$$\overline{U_k} = \alpha U_k + (1-\alpha)\overline{U_{k-1}} \text{ where } 0 < \alpha < 1 \tag{4}$$

The *mean absolute deviation* (*MAD*) of the time-based usability is defined by

$$MAD(U) = \frac{1}{M} \sum_{i=k-M+1}^{k} \left| U_i - \overline{U_k} \right| \tag{5}$$

where the chosen sample size for statistics is *M*, that is, the number of samples to be stored in a mobile-web name-based directory DB as metadata for estimation, the samples have values U_i , the mean is $\overline{U_k}$ ($k > M-1$) and $M \approx \frac{1}{\alpha}$.

If the smoothing parameter α is too small, *M* becomes larger. For many sessions, if M_s is the number of sessions in a web information server, then the memory size for real-time estimation of the time-based usability as stochastic random variable becomes $M_s * M = M_s * \frac{1}{\alpha}$.

The random variable, time-based *Accessibility: A***,** required for real-time estimation can be estimated as follows:

$$\overline{A_k} = \beta A_k + (1-\beta)\overline{A_{k-1}} \text{ where } 0 < \beta < 1 \tag{6}$$

The *mean absolute deviation* (*MAD*) of the time-based accessibility as a stochastic metric is defined by

$$MAD(A) = \frac{1}{N} \sum_{i=k-N+1}^{k} \left| A_i - \overline{A_k} \right| \tag{7}$$

where the chosen sample size for statistics is *N*, *that is*, the number of samples to be stored in a mobile-web name-based directory DB as a metadata for estimation, the samples have values A_i, the mean is $\overline{A_k}$ ($k > N-1$) and $N \approx \frac{1}{\beta}$. The right place for real-time estimation may be chosen on the basis of requirements and a kind of web server program. For example, the *global.asa* in ASP web server program is proposed for simple implementation of *real-time estimation* of session time and frequency (i.e. the number of sessions by users within a time period) of sessions to estimate the stochastic random variable in real-time.

4 Implementation and Discussion

We implemented a mobile-web name-based directory service accessible with a single-character multilingual alphabet (domain names) as well as with the English alphabet for good time-based usability and accessibility. The ubiquitous name-based directory service is especially context-adapted to the mobile-web interaction in the ubiquitous Internet. We present the ubiquitous name-based directory service, then discuss with the empirical results for mobile-web interactions and the time-based usability and accessibility.

4.1 A Mobile-Web Name-based Directory Service

Mobile web-based services fall into three categories: personalization, context awareness, and content adaptation [Canali, 09]. Personalization and context-aware services already perform the most expensive tasks offline. Services for the mobile-web are placing and will place an increasing demand on underlying server infrastructures because of the need to tailor contents to user preferences, contexts, and device capabilities. Instead of multimedia contents, we implemented a simple text-based directory service. Instead of pushing style service such as a spam message, we considered the pulling style service in our implementation of ubiquitous mobile-web name-based directory service.

Information architecture is defined as "*the structural design of shared information environments*" [Maicher, 09]. It is defined as "the art and science of organizing and labeling web sites, intranets, online communities and software to support usability and find-ability." The efforts of the information architecture are focused on two goals: increasing the value of the users and decreasing the costs building and managing information systems. A portal represents a domain, and the portal must be driven by the *domain model*. Each domain consists of different subjects that are variously intermixed by differently typed relationships. Such subject-centric domain models must define the interaction and interface design. These portals, reflecting the domain as it is, will directly result in an increased experience with added value for the users. We use 300 usable multilingual domains (TLDs).

A ubiquitous name-based directory service for human mobile-web interactions is especially context-adapted to the ubiquitous Internet, many single multilingual (e.g. Korean) character domain names (e.g. converted ASCII Punycode format: 'http://xn--ypd.net', 'http://xn--4pd.net', 'http://xn--4k0b.net', etc.) for multilingual users. The notification information with multilingual domain model can be registered at any time and at any place using the ubiquitous Internet, in a web site for the human-centric ubiquitous web information service, i.e. the 'http://ktrip.net'. We considered the text-based messaging service with the simplicity for different user profiles as well as adapted contexts of use (e.g. SNS, lecture group, alumni association community, etc.).

For multilingual users, we implemented a mobile-web name-based directory server accessible with a multilingual single-character domain name's ASCII Punycode, e.g. 'http://xn--ypd.net', etc. We implemented the name-based directory service with a single-character multilingual alphabet (domain names) as well as with the English alphabet for stochastic metrics such as time-based accessibility and usability. As an example of ubiquitous web information services using a mobile-web name-based directory with various mobile phones serviced by many mobile service operators, we used the ASP server program based on Microsoft IIS web server and SQL DB server for various mobile phones of a user. Utilizing this program for web information interaction by a user, the ubiquitous mobile-web directory server as information portal, 'http://ktrip.net' can be accessed in a unified way by a variety mobile phones with single-character multilingual TLDs (e.g. converted ASCII Punycode format: 'http://xn--ypd.net', 'http://xn--4pd.net', 'http://xn--4k0b.net', etc.) related to the first character/alphabet (consonant or vowel) of each multilingual search keyword. Keywords between <title> </title> tags in the ASP or HTML script were crawled as searched titles by commercial search engines. The keywords are usually fixed in the ASP or (m)HTML program in the mobile-web server, therefore real-time updating of the keywords as search titles is not possible. Our presented (name-based) directory server accessible with over 300 TLDs is adapted to real-time registration, search and crawling for search engines. However, with current commercial search engines, publishing of new information with the appropriate search-title is not possible in real-time.

For implementation in the '*global.asa'* of the ASP web server program on a web site, we studied the real-time estimation of stochastic metrics, i.e. time-based accessibility and usability. Simple implementation of real-time estimation of the session time as time-based accessibility and the number or frequency of sessions (for estimation of time-based usability) can be estimated to analyze and evaluate the human mobile-web interaction in real-time. In the ASP program, the following event handlers of the application object can be used for simple implementation of unified estimation scheme for real-time estimation. In the event handlers, i.e. '*session_onStart'* and '*session_onEnd'*, the session time and the number of sessions can be estimated in any web site to estimate the stochastic random variables (i.e. *time-based usability and accessibility*), in '*global.asa'* program for real-time registration and search of mobile-web information in social networking.

We implemented the name-based directory service with single-character multilingual alphabet as well as with the English alphabet as following *Figure 4*. In the figure, different type options can be selected (e.g. ‘My’ type option - my personalized directory with privacy using private password for a user). *Figure 4* below shows a unified-ubiquitous mobile-web name-based directory with multilingual and English alphabets. The simplified multilingual directory is optimized for being embedded in small screen of any mobile phone including smart phones (i.e. iPhone, Android phone, etc.), with consideration of time-based usability and time-based accessibility for real-time registration and search of mobile-web information for SNS in ubiquitous Internet environments.

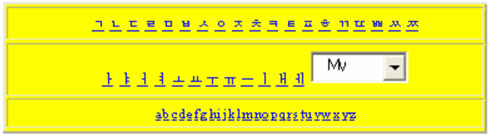

Figure 4: A Unified-Ubiquitous Name-based Mobile-Web Directory (with a multilingual alphabet and English alphabet)

Figure 5 below shows examples of the ubiquitous name-based directory service for human-centric mobile-web interactions with mobile phones as well as PCs.

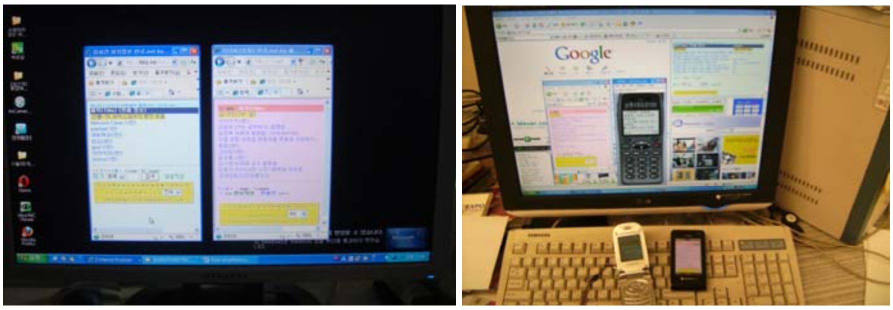

Figure 5: Examples of a Ubiquitous Name-based Directory Service (for Mobile Phones and PCs)

The speed of real-time registration of any mobile-web information as well as the speed of access of special information for various communities is fast enough for real-time interactions for ubiquitous mobile-web information services. Moreover, the effectiveness and efficiency of storage for information in a ubiquitous name-based directory service could be expected if we consider efficient worldwide applications for various multilingual users, in terms of the consumed disk storage, operation and administration.

We implemented a ubiquitous name-based directory service with good *time-based usability and accessibility* for mobile-web interactions in the ubiquitous Internet environment. The ubiquitous mobile-web server, with *ASP branch program*, is capable of showing the appropriate mobile-web contents for many different kinds of mobile devices including smart phones.

4.2 Mobile-Web Interactions

The user interface for service discovery as well as social information search for SNSs with a ubiquitous name-based directory must be convenient even for typing-in the domain names or URLs with mobile phones. Indeed the first step for mobile-web service in the ubiquitous Internet environment is typing-in the URL of the targeted mobile-web site offering the requested information or service. The deterministic time for mobile-web interactions was possible with the deterministic size of packet, below around 3 Kbytes (i.e. over 20 times of one 140byte-tweet in Twitter), which is enough size for any social information/message. From the empirical results of the mean and standard deviation of 100 samples, we observed that the average response time (just to access the mobile-web site before reading hyper-linked contents) with mobile Internet was around 12 seconds with about 2 second standard deviation.

Referring to the aforementioned *Figure 2,* with various mobile phones of 50 students in a lecture group, the average interaction delay of **M** (the typing time of a URL, i.e. 'ktrip.net') is about 30 [sec] with standard deviation (14.3 [sec]). The average of $\mathbf{W}_{(ktrip.net)}$ is about 9 [sec] with standard deviation (6.4 [sec]), the average of $\mathbf{W}_{(operator's\ portal)}$ is about 7.9 [sec] with standard deviation (5.8 [sec]). The average time of reading hyper-linked contents is about 6.8 [sec] with standard deviation (7.3 [sec]). We need to continuously try to decrease the interaction times **P** and **M**. We can also use speech recognition technology to decrease the interaction time **M**. Google Voice Search would reduce the device interaction time **M** in mobile-web interactions for searching. Single key for *'.com*' or *'.net'* provided in smart phone such as iPhone is efficient in terms of click number. In the previous Figure 2, we tried to decrease the major interaction times: Mean(**P**) and Mean(**M**), as well as the network and server interaction time Mean(**W**) (or for Contents in DB, Mean(**C**)).

For a semantic ontology represented by a syntactic structure, we considered the simple semantic matching of human-centric multilingual domain names and web information. As Internet top-level domains (TLDs) for unified mobile-web services, we used over 300 single-character multilingual domain names (TLDs) including tens of multilingual (Korean) alphabet domain names (TLDs) to find name-based information (e.g. name-card for SNS) as well as to notify name-based information in a real-time way in ubiquitous Internet environments. Speech recognition technology (e.g. Google Voice Search) would also decrease the interaction time, Mean(**M**), instead of keypad-stroke interaction. A mobile phone was used for testing of the international roaming service as well as the mobile Internet service in Japan and China. In Tokyo, Kyoto, Osaka, and Beijing, the primitive experiment of a ubiquitous web service for real-time access to information was researched. On the Japanese express train, the 'Sinkansen', moving at 300Km/hour, the registration of web information was possible. The reading of ubiquitous mobile-web information took approximately a similar amount of time as on the Korean express train 'KTX'. If we always carry mobile Internet devices such as iPhone, the preparation time **P** becomes almost negligible as ubiquitous computing and networking environment prevails.

From the experiments in Japan and China, we observed that the average interaction time with mobile phone for the first interaction to 'http://ktrip.net' web site was around 12 [sec] with a little deviation as in Korea. After an initial interaction with 'http://ktrip.net', the reading time for registered information was around 2-3 [sec]. The summated interaction time (**W**+**C**) was around 2-3 [sec] and was not comparable to the interaction time **M** that is at least over 30-60 [sec] depending upon the amount of text-based information for writing with keypads during the registration of information. The inconvenient interaction for writing URL or search keyword/name with keypads was a major bottleneck in the degradation of the overall performance in a session in human mobile-web interactions for SNSs. After the initial connection to a mobile-web interaction site with a unified name-based directory, we could search some specific information, a mobile-web name card, a bulletin board, or other familiar web sites registered in a ubiquitous mobile-web name-based directory accessible with a single-character multilingual domain names. The time-based *accessibility* in a session of reading contents (1~3 Kbytes text-based information), as a performance parameter, was around 17 seconds from the initial connection to a mobile-web site until the completion of the session of reading message in a ubiquitous name-based directory. The time-based *usability* increased as the usage frequency of sessions increased.

4.3 Time-based Usability and Accessibility

With commercial search engines (e.g. Yahoo, Naver, Daum, Google), 101 students registered their web-based name cards titled with their names in 'http://ktrip.net' site. The students tried to search their own name as a keyword for searching, and then they checked the elapsed time to be searched in each search engine. Of the 101 students, 58 students could search their name on the Yahoo portal, 24 students on the Naver (a major Korean portal), 9 students on the Daum (a Korean portal), and 17 students on the Google. The Yahoo engine showed the best performance; the minimum time to be searched was 6 hours, and the average time for 58 students to be searched was 137 hours. In our experience, a guaranteed (i.e. searched) service for real-time registration and search is impossible with the current commercial search engines.

Search Engine	**Yahoo**	**Naver**	**Daum**	**Google**
Crawled Name [Numbers] Among 101 Students (%)	58(57%)	24(24%)	9(9%)	17(17%)
Average Time to be searched [Hours]	137	242	162	223
Minimum Time [Hours]	6	24	24	24

Table 1: Real-time Performance for Registration and Search by Search Engines

We performed another experiment in a lecture group (as a special social networking) as follows. The number of students was approximately 1,200 over 10 semesters, or approximately 120 students a semester over a four month period. The cumulative number of clicks on the message notification board was around 77,600. This means that the average click number (usage frequency for time-base usability, i.e. number of sessions) on the message notification board in one semester for one student was roughly 4 clicks per week. As an example of mobile-web services for social networking, the time-based accessibility (around 30 [seconds]) and the weekly (i.e. time-based) usability (about 30*4 [seconds/week]) for a user; about 30*4*120 ([seconds/week] for a lecture group) with a ubiquitous name-based directory could be estimated simply with offline/online analysis. Similarly we can compare the time-based usability and accessibility between "Google.com' and 'Twitter.com' on the basis of offline/real-time analysis depending upon requirements and implementation. This is an example of comparisons among various web-based services. The real-time stochastic random variables, i.e. time-based usability and accessibility, can be stored in the mobile-web interaction server, as QoE metadata for applications.

Figure 6: Examples of a Ubiquitous Mobile-Web Directory Service (with iPhone and Android Phone)

With the test mobile-web site 'http://ktrip.net' and many other TLD (i.e. around 300 single-character multilingual alphabet domains), we were able to register and search a unified-ubiquitous mobile-web name cards in real-time with any mobile Internet device such as smart phones (e.g. iPhone and Android phone as shown in *Figure 6*) as well as with PCs using browsers (e.g. MS Explorer 7.0+, Firefox, Safari, Opera, Chrome, etc.) for real-time social networking. As other important issue, we have experience in terms of security attack (related to distributed denial-of-service attack) against our reliable directory service, which is an important issue for real-time mobile-web directory service. Various types of security attacks, particularly if carried out using administrative privileges, could compromise large amounts of directory information. Claycomb [Claycomb, 09] presented two approaches, i.e. centralized approach and distributed approach, for protecting directory services information from security attacks. Based on the centralized approach, we researched a unified and ubiquitous directory service for individuals, groups, and communities. In our 5-year experience with a directory server, we also found around 200 illegal spam advertisements registered, and we have been continuously protecting the ubiquitous name-based directory server from the security attack as well as from the registration of repetitive spam advertisements, with anti-hacking program and real-time IP checking in the ASP program.

Our concept could be implemented in our mobile-web name-based directory server, and the frequent modification of program is also possible. However, the limitation of our approach is the implementation of real-time estimation scheme in the running server for commercial service (e.g. Twitter). In that case, we may apply our concept with offline analysis as follows. According to a survey with 975 non-mobile SNS users (age: 20~44) (by Cheil Inc.) in Korea, weekly usage frequency was around 3 (69%) in mini Home-Page/Café (i.e. long session time) by PCs. Mobile SNS users' daily usage frequency was 5 (52%) with short message/tweet (i.e short session time) by smart phone. As other issue, if we define a *service-ability* for service competitiveness of mobile-web service as a function of *time-based usability and accessibility*, then the *service-ability* may be related to the usage frequency *f;* we leave that as a further research issue for emerging mobile-web services.

5 Conclusions and Future Work

Real-time analysis of *time-based usability* and *time-based accessibility* for human *mobile-web interactions* were studied for mobile-web information services with a ubiquitous name-based directory. The human mobile-web interaction in ubiquitous Internet environments was studied for estimating real-time stochastic random variables, i.e. *time-based accessibility* and *time-based usability*. We defined the time-based usability and accessibility based on mobile-web interaction session time and usage frequency, which can be estimated in real-time in the mobile-web interaction server interacting with various mobile Internet devices such as the iPhone and Android phone, etc. We discussed with empirical results based on the implementation of a ubiquitous mobile-web name-based directory server. As future work, the practical applications based on the real-time analysis of time-based usability and accessibility in a ubiquitous mobile-web directory server will be studied for real-time evaluation of mobile-web advertisements as well as for *service-ability* of mobile-web services.

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