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Accessibility and Usability of User-centric Web Interaction with a Unified-Ubiquitous Name-based Directory Service

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Abstract Web-based information services should be evaluated for accessibility and usability with various types of Internet Web-browsing devices, interacting with web information servers including directory server. A ubiquitous name-based directory server, accessible and usable with a variety of Web-browsing devices (e.g. Internet-capable mobile phones), could be a unified center for human-centric Web interaction services as well as for business models based on personalized services. We studied the accessibility and usability in user-centric Web interaction with a unified-ubiquitous name-based directory service, as metric metadata for real-time estimation. We studied the real-time metrics in synthetic approach for comparison among different services. We show empirical results based on implementation and experiments in Korea, Japan and China.

Keywords web interaction · user-centric · accessibility · usability · ubiquitous · directory

1 Introduction

A long-term goal of Human Computer Interaction is to design systems that minimize the gap between the human's cognitive conception of task and its computational representation [18]; the new computing today is a shift from machine-centered automation to user-centered services and tools. We have studied a user-centric and unified mechanism for the simplification of information access interaction in an environment flooding with information. Using two ways, i.e. wired Internet and mobile Internet, a ubiquitous Web information service with a unified directory service should be considered for efficient and usable interaction as well as for integrity of consistent information. As an example of specific user-centric application, we studied a ubiquitous Web information service with a unified-ubiquitous name-based directory for social networking [14] including the disabled and the elderly in the aged society. Social networks are "explicit representations of the

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relationships between individuals and groups in a community. In the abstract, these networks are just simple graphs with nodes for the people and groups and links for the relationships." [8, 17].

The Web server using a ubiquitous directory (accessible ubiquitously with any Internet-capable device anytime, anywhere) is a role center in user-centric Web interaction for a ubiquitous Web information service and real-time Web-activity analysis. The client mobile devices for Web information access become very important for social networking interaction in ubiquitous computing and the networking environment. For the performance of Web information access using a name-based directory server, we considered several aspects (e.g. human-centric accessibility and usability) about the Web server for Web interaction. The performance of a worldwide web (WWW) service as a service platform became a central issue in providing a ubiquitous, reliable, and efficient information network for ubiquitous Web information services. The performance issues in the worldwide Web servers were studied [7], and the mechanisms to reduce the number of packets exchanged in an HTTP transaction were presented. For wired Internet using HTML, for PCs, and for mobile Internet using WML or mHTML, for mobile phones, management of the Web server becomes more difficult; Hwang et al. [12] studied the case of WAP (wireless access protocol) site from this point of view. The wireless, mobile Web promises to provide users with anytime, anywhere access to the same information; ubiquitous Web access should also facilitate greater acceptance of new services such as location-based shopping (based on personalized advertisements), which are specialized for mobile use [24].

An approach to website personalization was introduced [9] on the basis of the exploitation of user browsing interests together with content and usage similarities among Web pages; user-centered access was considered with some different user profiles. Some researchers [36] studied the relationship between user behaviors and user preference during Web browsing on small screen devices to find user's interest blocks with offline statistical analysis.

We have studied the accessibility and usability of user-centric Web activity for ubiquitous Web information services as well as for the personalized advertisement, using a unified-ubiquitous name-based directory server and mobile phones for many user (or group) profiles (e.g. SNS user, lecture-group), with real-time estimation approach for realistic measurement.

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 and relevancy of their returned results are still not satisfied in many cases, and search engines usually return a lot of links of Web documents but still cannot guarantee the relevancy to the user's question [34].

"When browsing information on large (even on smaller) Web sites, users often receive too much irrelevant information. The vast amount of irrelevant information on most these Web sites can overwhelm users, leading to the study about personalized Web views for multilingual Web sources" was introduced by Liu et al. [16]. User navigation patterns were studied by modeling user navigation [10]. To avoid users browsing against over thousands of results, Ruvini [28] introduced the study of adapting to the user Internet search strategies.

Twitter is the hottest social medium around. The microblogging application enables anyone with Internet access to issue short public messages [27]. Twitter's search service does not consistently deliver real-time results: 20 or more minutes often pass before a given tweet appears in search results [32]. Some Web sites such as news 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 advertisement) at the user's viewpoint, it takes a long time to register new information in a Web site and be searchable by commercial portals (e.g. around 5~7 days by Google, around 6 h~1 day by Yahoo, over one week by other portals). For multilingual users, we tried to find a better way for the real-time information registration and advertisement, i.e. for real-time publishing and real-time searching. Considering accessibility and usability for multilingual users, we also studied a more efficient way to find rather familiar information used frequently such as a web-based name card, web-based phone numbers (of friends, relatives, or alumni), and blog URLs, etc.

Usability and Accessibility (U&A) guidelines have been set up to help designers in the process of creating usable and accessible sites [16]; W3C consortium recommendations for accessible Web sites, the Web Accessibility Initiative (WAI) recommendations, and the Web Contents Accessibility Guidelines. We studied accessibility and usability of user-centric Web interaction with multilingual domain names for a unified-ubiquitous name-based directory service. We tried to find unified metrics for comparison among even different types of services.

In the following sections, we introduce backgrounds with related studies; we discuss the accessibility and usability of user-centric Web activity in wired and mobile Internet, especially with human interaction from the user's perspective. We will discuss the accessibility and usability of user-centric Web interaction as real-time stochastic metrics, and discuss our experience that we acquired in Korea, Japan and China, with the empirical results based on implementation of a ubiquitous Web information service based on a unified-ubiquitous name-based directory. Finally, we will conclude our study with consideration of further research.

2 Backgrounds and related works

Activity theory is a psychological meta-theory, paradigm, or framework, with its roots in the Soviet psychologist Vygotsky's cultural-historical psychology [35]; activity theory theorizes that when individuals engage and interact with their environment, production of tools results. These tools are exteriorized forms of mental processes, and as these mental processes are manifested in tools, they become more readily accessible and communicable to other people, thereafter becoming useful for social interaction. The most important tenet of active theory is its tool mediation concept [15]. Facilitating communication and information processing, computers are regarded as tools that mediate between human actors and objects targeting an outcome. Having an important implication of social networking, this mediation is not merely between a person and the object, but also with other people. Tools are carriers of culture and social experience. Tool mediation implies two interfaces. One is the interface between the user and the computer and the other is the interface separating the outside world from the user and the computer.

Some researchers studied to build a context classification model based on Activity theory [13]. Researchers have attempted to improve user interaction through the notion of context awareness by exploiting information relating to users, devices and environments. Activity theory is introduced as a potentially valuable approach to developing a comprehensive context classification with an example scenario used to demonstrate how different types of context and their relationships may be identified. The activities, after all, are human activities, so they reflect the possible range of actions, of conditions under which people are able to function, and the constraints of real people [22]. To the human-centered design community, the tool should be invisible; it should not get in the way. With activity-centered design, the tool is the way.

In many countries, better access to Web services and Web administration is becoming an important issue; and a few action lines of improvement for the Web Content Accessibility Guidelines are suggested [6]. Universal access implies the accessibility and usability of Information Society Technologies (IST) by anyone, anywhere, anytime. It is important that the needs of the broadest possible end-user population are taken into account in the early design phases of new products and services. Universal Design in the Information Society has been defined as the conscious and systematic effort to proactively apply principles, methods and tools, in order to develop IST products and services that are accessible and usable by all, thus avoiding the need for a posteriori adaptations or specialized design [31]. Internet accessibility beyond disability was also studied by Hofstader [11]. New approaches and related instruments are needed for capturing human requirements in the new reality. Appropriate architectural framework and development tools will also need to be elaborated in the age of the disappearing computer [30].

We considered the implementation of a unified-ubiquitous name-based directory service with good accessibility and usability of Web interaction in this ubiquitous computing and networking environment. A relatively large set of metrics have been introduced in the accessibility and usability literature. Instead of specific accessibility (e.g. Web contents accessibility), we considered the accessibility based on time metric for real-time estimation and comparison among different services for any users (i.e. the disabled or not). We also considered that accessibility for real-time estimation of usability as another random variable in real-time measurement for any users with common metrics. We studied the human-centric accessibility and usability for real-time quantitative estimation with synthetic approach instead of analysis with various qualitative factors, considering relative Web-activity among various human activities.

Accessibility was studied on the basis of quantitative metric such as time [second]; the usability has not been studied much with the quantitative metric instead of some qualitative evaluation. We found some correlation between accessibility and usability, and we used the time [second] metric for simplicity as a quantitative metric as well as a comparative metric with other homogeneous/heterogeneous services.

In a ubiquitous computing environment, service discovery protocols (SDPs) must find the most appropriate services; handheld devices have limited resources and user interfaces, so users shouldn't be presented with a long list of discovery results; SDPs must find useful services automatically because users might not be aware of the available services. By personalizing discovery, it lets users find the most appropriate services for their immediate situation; they are trying to help mobile phone users find appropriate services according to their preferences and contexts [23]. The user interface for service discovery with a unified-ubiquitous name-based directory must be convenient even for typing-in the domain names or URLs with mobile phones because the first step for Web service with wired/mobile Internet (especially, with mobile Internet) is typing-in the URL of the targeted Web site offering the requested information or service.

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 browsers as a built-in functionality, e.g. from the version of MS IE7.0 and Firefox, Opera, Google Chrome, etc.

For multilingual users, we need to consider the relationship of semantics and syntactic structure related to search keyword(s). We considered domain names based on multilingual language and English for semantic applications. As Cudre-Mauroux et al. [5] studied, the semantics of a syntactic structure is a relationship between a syntactic structure and some domain; in many cases, humans are responsible for providing software agents with their initial semantics; natural language vocabulary is used for the local symbols while the associated relationship with the corresponding explanation or definition of the notion concerned is very often left implicit. "Explicitly represented semantics of a syntactic structure in an information system consists of a relationship between this syntactic structure and some generally agreed-upon syntactic structure. Thus, the semantics is represented itself by a syntactic structure" [5]. We considered the relationship between the ontology of a knowledge domain and multilingual keyword(s) based on natural languages. Ontologies can be regarded as an effective way to model different aspects of a user interface and to provide conceptual models in which complex relationships can be defined [18].

For real-time information access users, even the input of a text-string search keyword becomes important for the retrieval 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 unified directory service ubiquitously, the user interface for a user should be as convenient as possible even for typing-in the multilingual domain names, URLs, or information. For writing a search keyword in real-time way, the user's typing speed of a text-string is one of important performance factors, especially with mobile phones. More convenient keypad-pressing is required for the mobile phone user to access information with a keyword using a unified-ubiquitous name-based directory service. We considered the accessibility and usability of user-centric Web interaction with mobile phones as well as with PCs, especially using a test-bed Web-based directory server accessible with many simple (single-character) multilingual domain names related to search keyword(s).

Real-time search begets real-time spam [32]. Spam targeting real time search engines http://www.spamhaus.org/definition.html; following the success of real time search engines such as the one incorporated at Twitter, a microblogging service, spammers are using topics to be seen among the legitimate results. Finding a way to filter these results is still a work in progress. Data quality represents a common interest between data consumers and portal providers; data quality is often defined as "fitness for use". Several research projects have been conducted on the topic of web data quality; however, there is still a lack of specific proposals for the data quality in Web portals which consider the data consumer's point of view as well as tools that put these proposals into practice [3]. Malik and Bouguettaya [19] investigated the problem of establishing trust in service-oriented environments; they presented a framework to evaluate the credibility of service raters for feedback based service-oriented reputation systems. The features of websites that we visit regularly, that differentiate them from websites that we don't 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) [26]. According to Pemberton's comments, "device independence, accessibility and usability are surprisingly closely related."

Norman mentioned that the field of human–computer interaction (HCI) has long stressed interaction, but primarily through the study of the effectiveness of various means of constructing systems for a wide variety of activities and situations [21]. Effectiveness has been measured by such items as usability, understanding, the number of errors, and the amount of time required to complete a task. Although usability and understandability are never goals, they are means toward the goal; pleasure, enjoyment, and fun can be goals.

The definition of *usability* for mobile devices was referred [2] 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. [1]; they introduced the idea that "the general process of performing an automated evaluation of a Web site could be decomposed into the following sequence of four main steps:

Step 1: Collecting U&A (usability and accessibility) data with their corresponding metrics, e.g. task completion time, errors, guideline violations, etc.
Step 2: Analyzing collected U&A data to detect U&A problems with the Web site.
Step 3: Reporting analysis results to the end user, e.g. Web site designer, owner, and visitor.
Step 4: Suggesting solutions or improvement to repair the previously detected problems."

Sutcliffe and Angeli [33] assessed interaction styles, i.e. traditional menu-based and interactive metaphors, in the Web user interface, and they found that the menu-based interaction style was superior for *usability* and information quality. The usability of mobile devices and their applications is a key factor for the success of mobile computing. Betiol and Cybis [2] studied usability evaluation of mobile interfaces based on three different evaluation approaches; they mentioned the importance of the context of 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 [25].

Seffah et al. [29] studied usability in ISO standards, i.e. ISO 9241-11 (1998) and 9126-4 (2001), proposed that "Usability (focused on software) is generally a relative measure of whether a software product enables a particular set of users to achieve specified goals in a specified context of use. Usability can vary from a user to another one and in general with the context of use, e.g. user profiles, task characteristics, hardware, software, and physical or organizational environments."

The unified Web server with good accessibility and usability should be capable of showing the appropriate contents, i.e. the HTML contents for wired Internet as well as the mobile contents for many different kinds of mobile devices, e.g. WML, mHTML etc. We implemented a simplified and unified portal with a unified-ubiquitous name-based directory for ubiquitous Web information services with wired Internet by PCs as well as with wireless Internet by mobile devices. Instead of a qualitative approach, we tried to find quantitative metrics of accessibility and usability for real-time estimation and applications in the ubiquitous computing and networking environment.

3 Accessibility and usability of user-centric web activity

We considered aforementioned concept about human-centric *accessibility* and *usability*, and we focused on the real-time quantitative metric instead of qualitative metric. The metrics, i.e. accessibility and usability, are stochastic random variables, and should be estimated in real-time for real-time applications. Depending on the phase of the software life cycle in which they are applied, usability metrics can be classified into one of two major categories, testing and predictive [29]; data from testing metrics are collected in order to measure the actual use of working service.

Jakob Nielsen [20] 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 the comparison among different usability may be very difficult or not possible. We believe that usability is very relative and stochastically changing and is being affected by other services/products because of the 24 h time constraint in human activity. We tried to find the *usability* as a common metric for real-time estimation and real-time comparison among different services.

We considered the accessibility and usability of Web interaction with single-character multilingual domain names (e.g. converted ASCII Punycode format: 'xn–ypd.net', 'xn–4pd.net', 'xn–4k0b.net', etc) as single-character keys for a unified-ubiquitous name-based directory service, at the user's viewpoint. The real-time application, getting required information as well as writing information in the wired and mobile Internet environment, was considered.

Activity theory posits that an activity is meaningful with actions [17], and actions are meaningful with operations; activities, actions, and operations are not static structures. We considered the activity (e.g. goal is to publish and search specific information using wired/mobile Internet), actions (e.g. some sessions with mobile phone or PC), and operations (e.g. real-time interactions discussed as follows).

We studied the important metrics of accessibility and usability with user-centric 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 Web sites about accessibility and usability). We analyzed the metric with time (delay), mainly with the spent time by user and the input time on keypads for URL(s) or search keyword(s) in the user-centric interactions.

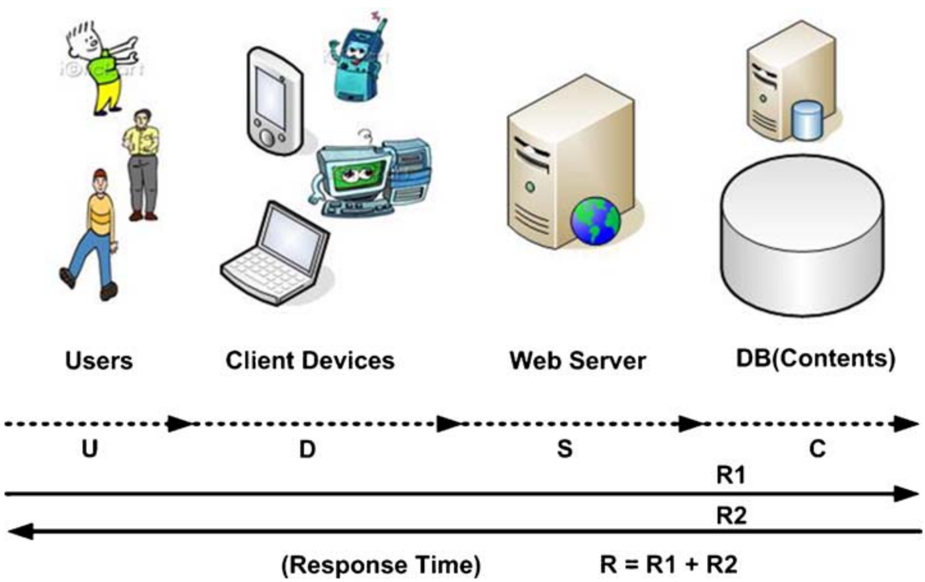

Figure 1 Operations (interactions) in an action (session) of web activity (for accessibility and usability).

For example, in Figure 1 for a mobile user, we assume that the random variables, the round-trip response time for a user's single interaction in a session, from a user to the contents in DB through wired/mobile Internet before next interaction with a mobile phone is *R1*. That is composed of the preparation time for any user in the ubiquitous computing and networking environment to get a mobile device for interaction in his hand is *U*. The time spent by the user with the mobile phone to do appropriate interaction for service is *D*. The aggregate interaction time to the Web server after the mobile device through wired/mobile Internet for mobile service is *S*, and the network time is embedded here. The interaction time depending upon mobile contents is *C*. Therefore the operation time in an activity is composed of *U, D, S, C*. We considered the accessibility as well as the usability for user-centric Web information services on the basis of the real-time estimation of stochastic random variables.

The session time based on interactions (i.e. operations) may be dependent on this content retrieval or registration, and there may be several back and forth iterations during the session (i.e. action). The returning round trip time in the session (action) , from the content retrieval time to the requesting user through Web server and wired/mobile Internet using mobile device, is *R2*. Among the above random variables, i.e. the performance metrics, (*U, D, S, C*) for mobile user and PC user, the most dominating factor, i.e. the random variable, may be different from person to person as well as from service to service. The previous works for computer networking has been mainly focused on the analysis of the random variable time, *S*, as well as other individual random variable times, but we suggest the average overall metric for evaluation of a session (action). For example, the average delay of a session, i.e. the response time Mean(*R)*, instead of the partial and minor delay *S*, for all users in ubiquitous Web information service. The user preparation time for interactions (operations) or ubiquity metric, Mean(*U)* will decrease depending upon the proliferation of the ubiquitous computing and networking environment.

For the real-time application using wired and mobile 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 Web information services.

As an example for multilingual applications, let's consider the average keypad press number in the case of a handheld phone model; this is related to the device time Mean(*D*). 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 Internet services with the mobile phone. This is also a critical dominating factor related to the time, *D*, especially for writing contents of information with a mobile phone. In Figure 1, we showed a simple example with a single iteration, however there may be actually several iterations in a session as shown in Figure 2. We studied the human-centric *accessibility* and *usability* in user-centric service; a service must be *accessible* for the service to be *usable*. We discuss the human-centric accessibility in a session, and then we will discuss the human-centric *usability* based on the *accessibility*. We tried to find a fundamental metric based on time [second] for simplification; the stochastic estimation of the random variables for the *accessibility* and the *usability* was studied on the basis of real-time time-series analysis.

In Figure 2, the time delay for user-centric Web interaction (operation) in a session (action) by several elements (i.e. user, device and Web server with a directory) are shown and broken down as follows: user preparation time for interaction (operation), U_1; interaction (operation) time with client's device, D_1 and D'_1; interaction (operation) time in network and Web server, S_1 and S'_1; user interaction (operation) time for understanding and

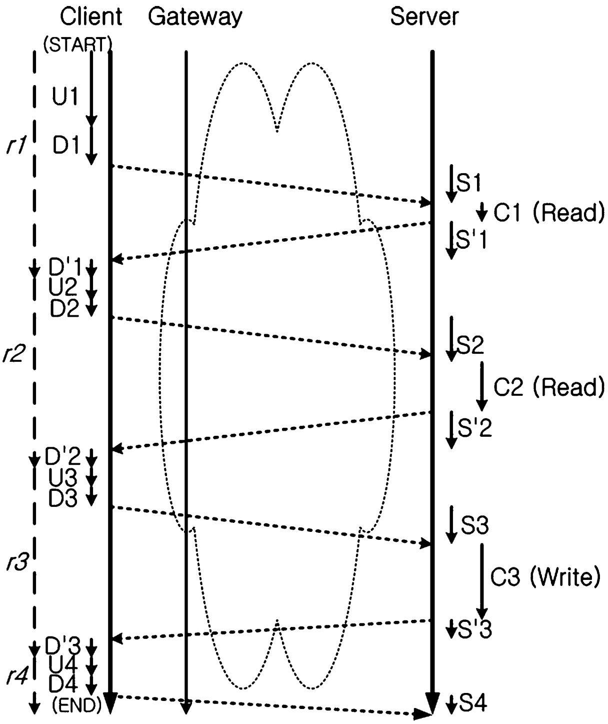

Figure 2 User-centric web interaction in a session (action) in mobile web activity.

readiness, U_2; interaction (operation) time with client's device, D_2 and D'_2; interaction (operation) time in network and Web server, S_2 and S'_2; interaction (operation) time for reading contents in the DB server, $C_{1(\text{Read})}$ and $C_{2(\text{Read})}$; user preparation interaction (operation) time for understanding and readiness, U_3; interaction (operation) time for writing contents with user's device, D_3 and D'_3; interaction (operation) time in network and Web server, S_3 and S'_3; interaction (operation) time for writing contents in the DB server, $C_{3(\text{Write})}$; user's preparation interaction (operation) time for understanding and readiness, U_4; interaction (operation) time for finishing the session with user's device, D_4; interaction (operation) time in network and Web server, S_4; finally a session (action) for mobile Web activity completes.

From Figure 2, for user-centric evaluation, the response time for *ith* interaction (operation) at the user's viewpoint, $r_i = U_i + D_i + D'_i + S_i + S'_i + C_i$. The overall interaction (operation) delay for a session in information access is $R = \sum_{i=1}^{n} r_i$. R, which is the response time in Figure 1, is related to the *accessibility* [second] ("how fast to complete a session (i.e. action composed of interaction operations)?") of a session (action) for a Web activity in our discussion. For real-time estimation the session (action) time could be estimated on the basis of easy implementation in the programs (such as ASP, JSP, or PHP) running in the Web server.

$$Accessibilty = R = \sum_{i=1}^{n} r_i \ [second] \tag{1}$$

In this session (action) with user-centric interactions (operations), the dominating factor is U_i and D_i in normal network and server, considering the recent stable network and server.

For real-time interactions using wired and mobile Internet, the dominating factor and the variance of that averaged random variable should be bound with the deterministic response time (i.e. the completion time of an action or session). To be deterministic in real-time Web activity, the user should be skilled, the user interface should be convenient, the network should be stable if possible, the server should be efficient and have high performance for the application, and finally the contents for a ubiquitous Web information service should be as simple as possible with a simplified and efficient format for user-centric interactions. The bandwidth requirement for wireless or mobile Internet should be low in order to be immune to the network traffic conditions for real-time interactions. Moreover that will be good against degradation caused by the other rich multimedia contents. The user's average preparation time for interactions (operations), Mean(U), will be shortened depending upon the proliferation of ubiquitous devices for Web activity, e.g. Internet-capable mobile phones.

The *usability*, which should be estimated in real-time way as a quantitative metric (i.e. "how much usable per day?"), could be defined with the equation, $\sum_{j=1}^{f} A_j$, where f is the number of daily sessions by the same or different users, i.e. frequency per a day (or 24 h); the f is random variable related to usage of a service (e.g. Google search, Twitter service, etc.) by a user or by a community (or by any group). A_j is the accessibility in j_{th} session (action) for a Web activity in a day, therefore the usability is the daily (or hourly, daily, monthly, yearly as an interested period) summation of the accessibility, as follows:

$$Usability = \sum_{j=1}^{f} A_j \approx \overline{A}*\overline{f} \quad [second] \tag{2}$$

For simplicity in our discussion, the (hourly, daily, monthly or yearly) *usability* could be approximated with the multiplication of the mean of *accessibility* and the mean of (hourly, daily, monthly or yearly) usage frequency f. In Eq. 2 the dimension will be dependent on the dimension of the frequency f, however eventually we can use the usability without dimension. Smaller the value of *accessibility* [second] for completion of an action (session) is, more accessible the action in an activity (Web service) for a user is. Larger the value of *usability* [second] is, more usable the Web service (activity) for a user or group is. With this concept, we can compare the usability with a common time metric among different type of services. For example, the usability of Google service for a specific user as well as worldwide users may be compared to the usability of Twitter service for a specific user and worldwide users in real-time way on the basis of a common time metric. We found that the accessibility and usability are not constant and they are stochastically changing random variables. The other services or activities are affecting the usability, and new services or other activities will affect the accessibility including the usability of a specific user or user groups (e.g. various communities). For more usable service, the accessibility will become smaller, and the frequency of usage of the service (activity) will be larger; the usability (i.e. the multiplication of accessibility and usage frequency) will be increased.

The human-centric *accessibility* and *usability* (Eqs. 1 and 2) could be used for both offline analysis and real-time analysis. We studied the real-time estimation of statistics (e.g. *Accessibility, Usability, f*) as metric metadata stored in a unified-ubiquitous name-based directory. 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. *Accessibility, Usability, f*). To find the statistical outlier we need deviation value, and we used the mean absolute deviation (*MAD*) model to reduce the complexity of real-time estimation. The random variable, *Accessibility: A,* required for real-time estimation can be estimated as follows:

$$\overline{A_k} = \alpha A_k + (1-\alpha)\overline{A_{k-1}} \text{ where } 0 < \alpha < 1 \tag{3}$$

The *mean absolute deviation* (*MAD*) of accessibility is defined by

$$MAD(A) = \tfrac{1}{N} \sum_{i=k-N+1}^{k} \left| A_i - \overline{A_k} \right| \tag{4}$$

where the chosen sample size for statistics is *N, that is, the number of samples to be stored in a name-based directory DB as metric metadata for estimation*, the samples have values A_i, the mean is $\overline{A_k}$ $(k > N-1)$ and $N \approx \frac{1}{\alpha}$. The random variable, *Usability: Us*, required for real-time estimation can be estimated as follows:

$$\overline{Us_k} = \beta Us_k + (1-\beta)\overline{Us_{k-1}} \text{ where } 0 < \beta < 1 \tag{5}$$

The *mean absolute deviation* (*MAD*) of usability is defined by

$$MAD(Us) = \tfrac{1}{M} \sum_{i=k-M+1}^{k} \left| Us_i - \overline{Us_k} \right| \tag{6}$$

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

If the smoothing parameter β 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 becomes $M_s{*}M = M_s{*}\frac{1}{\beta}$. The right place for real-time estimation may be chosen on the basis of requirements and also a kind of server program, for example the *global.asa* in ASP Web server program may be considered for simple implementation of real-time estimation of session (action) time and frequency (i.e. number of actions within a time period).

We recommend the pulling-style service (by/for/of right users) instead of pushing-style (i.e. spam-style) service in an advanced ubiquitous information society. The pulling of information in the directory can be considered in a similar fashion as the sampling theorem, the pulling (i.e. sampling) frequency F_s, that is the frequency of pulling an information record in the information DB table, e.g. a searched Web site for mobile social networking service, and F_u is the frequency of notification (i.e. updating) by the association for mobile social networking service, then $F_s \geq 2F_u$. If T_u is the mean of updating periods with the appropriate smoothing parameter γ, and t_u is the random variable of updating time interval, then

$$T_u = \overline{t_u} = \gamma\, t_k + (1-\gamma)\overline{t_{k-1}} \text{ where } 0 < \gamma < 1 \tag{7}$$

The *sampling (i.e. pulling) frequency* F_s may be different for each random variable, and

$$F_s \geq 2F_u = \frac{2}{T_u} = \frac{2}{\overline{t_u}} = \frac{2}{\gamma t_k + (1-\gamma)\overline{t_{k-1}}} \tag{8}$$

(F_u is the updating or changing frequency of a random variable).

With the pulling (i.e. sampling) frequency F_s, a member in the social network needs to pull (or read) the information in the unified directory for user-centric ubiquitous Web information services. Smoothing parameters (α, β, γ) for real-time estimation could be the same number (e.g. 0.1 or 0.2) for simplification. Depending upon this pulling (or reading) frequency, the real-time automatic notification with F_s frequency using SMS (short message service) can be also implemented if needed in a real-time SNS.

4 Implementation and empirical results

Mobile Web-based services fall into three categories: personalization, context awareness, and content adaptation [4]. 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. The major performance challenges will likely concern services that adapt multimedia contents. Instead of multimedia contents, we implemented a simple text-based name-based directory service. Instead of pushing style service such as a spam message, we considered the pulling style service in our implementation of unified-ubiquitous name-based directory service. Spammers are numerous, because the barrier to entry is so low. The volume of unsolicited mail has become very high. The costs, such as lost productivity and fraud, are borne by the public and by Internet service providers, which have been forced to add extra capacity to cope with the deluge [3].

A ubiquitous name-based directory service for a user-centric Web interaction is based on wired or mobile Internet, many single multilingual (e.g. Korean) character domain names (e.g. converted ASCII Punycode format: 'xn–ypd.net', 'xn–4pd.net', 'xn–4k0b.net', etc) for multilingual users. The required information for multilingual users can be registered in any time and any place using wired or mobile Internet in a Web site for the user-centric ubiquitous Web information service, i.e. the 'ktrip.net'. We considered the text-based messaging service with the simplicity for different user profiles as well as different contexts of use (e.g. SNS, lecture group, alumni association, etc.).

The size of the Web page for a ubiquitous Web information service was optimized at below 1.5 Kbyte, i.e. between 500 Bytes and 1.5 Kbytes of compiled WAP binary, to minimize the dependency of the overall performance to the shared and stochastically varying network traffic. A Web server was developed for the user-centric ubiquitous Web information services with a unified-ubiquitous name-based directory.

For multilingual users, we implemented a unified-ubiquitous name-based directory service accessible with a multilingual single-character domain name's ASCII Punycode, e.g. 'xn–ypd.net', etc. We implemented the name-based directory service with single-character multilingual alphabet as well as with the English alphabet as following Figure 3. In the figure, different type option can be selected (e.g. 'My' type option — my personalized directory with privacy using private password for a user).

Figure 3 A unified-ubiquitous name-based directory (for different profiles) (with a multilingual alphabet and english alphabet).

As an example for ubiquitous Web information services using a name-based directory service with various mobile phones serviced by many mobile service operators, we used the ASP server program based on Microsoft IIS Web server and DBMS for various mobile phones of a user. With this program for Web information interaction by a user, the information portal, http://ktrip.net can be accessed in a unified way by different mobile phones with a single-character multilingual domain name related to a multilingual search keyword (e.g. converted ASCII Punycode format: 'xn–ypd.net', 'xn–4pd.net', 'xn–4k0b.net', etc).

The speed of real-time registration of any advertisement as well as the speed of access of special information for various communities is fast enough for real-time interaction for ubiquitous Web information services. Moreover, the effectiveness and efficiency of storage for information in a unified-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.

Considering the accessibility and usability of the unified portal, we could make the interaction time deterministic in the Web server for contents. The deterministic time was possible with the deterministic size of packet, below around 1.5 Kbytes, i.e. below one WML deck size for WAP-based mobile service. From the empirical results of the mean and standard deviation of 100 samples, we observed that the response time of the wired PC is fast and stable with little deviation because of the high bandwidth infrastructure, while the average response time with mobile phone Internet was around 12 s with about 2 s standard deviation; such results were similarly found in Korea, Japan and China.

Referring to Figure 1, the empirical performance with various mobile phones by 50 students (as user profile of a lecture group), the average interaction delay of *D* (the typing time of a URL, i.e. ktrip.net) is about 30 [sec] with Standard Deviation (14.3 [sec]). The average of $S_{(ktrip.net)}$ is about 9 [sec] with Standard Deviation (6.4 [sec]), the average of $S_{(operator's\ portal)}$ is about 7.9 [sec] with Standard Deviation (5.8 [sec]). The average time of reading-content is about 6.8 [sec] with Standard Deviation (7.3 [sec]).

We need to continuously try to decrease the interaction (operation) times *U* and *D*. We can also consider speech technology (instead of pressing keys in the automobile) to decrease the interaction (operation) time *D*. The 'Pen Phone' introduced by Siemens would reduce the device interaction (operation) time *D*. Standardization for user interface of mobile phone is important, and service providers and manufacturers of mobile phones have been attempting it. This will be also helpful to reduce the device time *D*.

We ordered the dominating factors in the overall performance from the user's perspective as follows. In general, in Figure 1, the relationship of mean interaction time in mobile Internet with mobile phone is Mean(*U*) > Mean(*D*) > Mean(*S*) > Mean(*C*). Here, we tried to decrease the major interaction (operation) times: Mean(*U*) and Mean(*D*), as well as the network and server interaction (operation) time Mean(*S*) (or interaction time for Contents in DB, Mean(*C*)).

For semantic ontology represented by a syntactic structure [5], we considered the simple semantic matching of human-centric multilingual domain names and Web information. As Internet URLs for unified Web services, we used over 300 single-character multilingual domain names including tens of multilingual (Korean) alphabet domain names as simple URLs to find information as well as to notify information in real-time way and ubiquitously for ubiquitous Web information services. Speech recognition technology would also decrease the interaction time, Mean(*D*), instead of text-based information interaction for a specific user.

A handheld phone model was used for testing of the international roaming service and mobile Internet service in Japan as well as in China. In Tokyo, Kyoto, Osaka, and Beijing, the primitive experiment of a ubiquitous Web service for real-time access to information, i.e. reading and writing information in anytime and anywhere, was studied. Even on the Japanese express train, the 'Sinkansen', moving at 300 Km/hour, the registration of personalized Web information was possible. The reading of ubiquitous Web information, of course, was easy and took similar amount of time as in Korea. On the Korean express train 'KTX' (i.e. Korea Train eXpress) the reading and writing of ubiquitous Web information has been possible. The interaction time U is almost negligible because we always carry our handheld phones in order to connect to mobile Internet, as ubiquitous computing and networking environment prevails.

From the experiments in Japan and China, we observed that the average interaction (operation) time with mobile phone for the first interaction to 'ktrip.net' Web site was around 12 [sec] with a little deviation as in Korea. After initial interaction to 'ktrip.net', the reading time for registered information was around 2–3 [sec]. The critical interaction time was the device interaction time D with mobile phone in our experiment, similarly as in Korea. The summated interaction time (S+C) was around 2–3 [sec] and was not comparable to the interaction time D that is at least over 30–60 [sec] depending upon the amount of text-based information for writing with keypads during registration of information. The inconvenient interaction (operation) for writing URL(s) or search keyword(s) with keypads was a major bottleneck in the degradation of the overall performance in a session (action) in a ubiquitous Web information service (Web activity). After initial connection to a user-centric Web interaction site with a unified-ubiquitous name-based directory, we could search some specific information, a Web-based name card, a bulletin board, or other familiar Web sites registered in a name-based directory accessible with a single-character multilingual domain names as syntactic structure representing semantics. The *accessibility* in a session of reading contents, as a performance metric, was around 17 s from the initial connection to a test Web site until the completion of the session of reading message in a ubiquitous name-based directory. The *usability* increased as the frequency of using sessions increased, as we discussed.

We performed another experiment in a lecture group (as a user profile) as follows. The number of students was approximately 920 over 8 semesters, or around 115 students a semester over a four month period. The cumulative number of clicks was around 68,000. This means that the average click number (usage frequency for usability, i.e. number of sessions) in one semester for one student was around 18 clicks per month. As an example of Web services for social networking service, the accessibility (around 30 [seconds]) and the monthly usability (about 30*18 [seconds/month] for a user; about 30*18*115 [seconds/month] for a lecture group) with a ubiquitous name-based directory could be estimated simply with offline analysis. Similarly we can compare the usability between Google user group and Twitter user group on the basis of offline analysis or real-time analysis depending upon requirements. This is an example of comparisons among various services.

5 Conclusions

The accessibility and usability based on user-centric Web interaction was studied for Web information services with a ubiquitous name-based directory service. Based on activity theory, Web activity in the real-time ubiquitous computing and networking environment was studied for estimating the stochastic real-time metrics of accessibility and usability. We defined the real-time metrics of accessibility and usability based on accessing time and accessing frequency which can be estimated in real-time. We showed empirical results based on the implementation in Korea, Japan and China. For future works, the practical applications based on the accessibility and the usability of mobile Web activity will be studied for real-time personalized advertisements as well as human-centric large scale real-time mobile Web applications.

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