A Methodology for Assessing the Level of U-Transformation of Ubiquitous Services

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Abstract

As the ubiquitous computing technology (uT) is prevailing, applying uT is more likely to transform the legacy way of doing business to a new way with the goals of ubiquitous computing: strategic use of information resources by using them everywhere, every time, with any devices for any services. These opportunities naturally require the provision to assess the degree of the transformation from the legacy IT-based e-business to the uT-based business. However, research about assessing the degree of u-transformation has been still very few. Moreover, even deciding what is 'ubiquitous' or not is obscure. Hence, this paper aims to propose the methodology for assessing the degree of u-transformation oriented by the teleology of ubiquitous service, which intends to fully make use of uT in creating new business of next generation. Through the literature review, we developed the methodology to check whether the provided service is ubiquitous or not based on the capabilities that technologies have. And then, the methodology developed to assess the technical requirements that the uT should have when the transformation is considered through the focus group interview based on the literature review of the capability. A two-layered approach is introduced to assess not only the level of ubiquity but also the degree of u-transformation.

Keywords:

Ubiquitous Computing Technology; U-Transformation, E-Business; U-Capability; Level of ubiquity; Location Based Service

Introduction

As envisioned by Mark Weiser(1991), one of the goals of ubiquitous computing is to provide various services by connecting multiple and embedded computing devices available around the physical environment. Another goal of ubiquitous computing is to integrate the real space with the virtual space, say cyberspace (Satoh I., 2003). To achieve the goals, assessing to what extent the systems or organizations embeds the ubiquitous features is very crucial as e-Transformation does. However, efforts to assess the degree of u-Transformation have been still very few. Moreover, even deciding what is 'ubiquitous' or not has been obscure. Meanwhile, as the research about e-Transformation has been conducted at organizational level (Leem, C.S. et al., 2003; Cheung, W.K.-W., 2004), the main focus of u-Transformation should be reached at the same level ultimately. However, current usage of ubiquitous computing technologies and services is in its early stage and too pre-mature to observe u-Transformation at organizational level. In this paper, therefore, we will focus only on evaluating the level of u-Transformation at individual level: assessing to what extent an individual environment such as house, cars and pendants is transformed into ubiquitously.

Hence, this paper aims to propose a methodology to assess the level of u-Transformation oriented by the teleology of ubiquitous service, which intends to fully make use of ubiquitous computing technology in doing new way of business.

In the remains of this paper, we review the related studies, propose an assessing methodology to identify level of u-Transformation, and show the feasibility of the methodology proposed in this paper with the examples of the actually conducting Location Based Services.

Related Studies

Ubiquitous Computing Services

Ubiquitous computing technology has a rich potential to provide innovative computer-based information systems that enable personalized and agile services. Concepts and artifacts of ubiquitous computing leverage traditional computer-based information systems in several key areas.

In particular, as information systems increase their intelligence, it will become more important for these systems to acquire knowledge and expertise in agile ways in order to provide employees and decision makers with relevant information. Ubiquitous computing technologies, therefore, that can be used to identify the user's context, and to recommend based on the context data, are well suited to current intelligent information systems.

Currently, researchers have proposed a variety of ubiquitous computing services. 23 services are selected from the literature and have classified them with two dimensions: technical viability and business viability (Lee and Kwon 2004). As shown in Figure 1, the services located in the lower left area of the figure are anticipated to be appeared shortly.

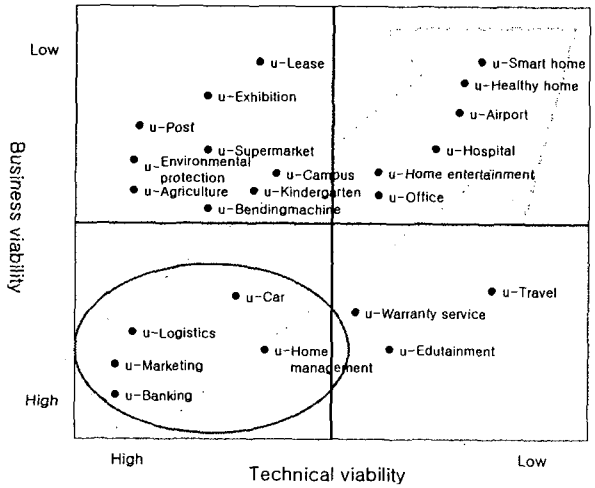

Figure 1 - Ubiquitous Computing Services

Evaluation of Ubiquitous Computing Technology and Services

Until now, there have been neither standardized nor generic criteria of evaluating the quality of ubiquitous computing services. Criteria suggested by most of the researchers also do not consider the generic issues but rather tend to focus on side issues about evaluating ubiquitous computing services solely based on their own research fields. Models and arguments for assessing ubiquitous computing systems and services are listed in Table 1.

Table 1 - Evaluation of Ubiq. Comp. Systems and Services

Authors	Content	Pers.
Riekki *et al.* (2004)	'Level of Calmness' of ubiquitous computing systems	T
Scholtz and Consolvo (2004)	Framework of Ubiquitous Computing Evaluation Areas (UEAs) - attention, adoption, trust, conceptual models, interaction, invisibility, impact and side effects, appeal, application robustness	B
Mankoff *et al.* (2003)	Evaluated ubiquitous computing focused on a specific filed, such as sensing systems	T
Bellotti *et al.* (2002)	Five interaction challenges - address, attention, action, alignment, and accidence	T & B
Friedman *et al.* (2001)	12 key human values with ethical import - human welfare, ownership and property, freedom from bias, privacy, universal usability, trust, autonomy, informed consent, accountability, identity, calmness, environmental sustainability	B
Spasojevic and Kindberg (2001)	Evaluating the CoolTown User Experience - Interference, Efficacy, Design implications	T
Quintana (2001)	Evaluation Methodologies for Ubiquitous Computing - Accessibility, Use, Efficiency, Accuracy, Progression, Reflectiveness	T
Richter and Abowd (2001)	Evaluating capture and access through authentic use - Quantitative: user logs - Qualitative: questionnaires, interviews, observations	B
Burnett and Rainsford (2001)	A Hybrid Evaluation Approach for Ubiquitous Computing Environments - Ubiquity/pervasiveness, Invisibility, Connectedness, Context-awareness	T
Basu (2001)	Metrics for Performance Evaluation of Distributed Application Execution in Ubiquitous Computing Environments - Speed, Quality, Efficiency, Resilience to Mobility, Application perf. after embedding	T
Dey (2001)	Metrics for Evaluating Ubiquitous Computing Systems - Configuration, Inference, Distractions/nuisance, Graceful degradation, Personal information, Ubiquity, Evolution	T

Table 2 - Explanation of Each Layer for Assessment

Layer	Assessment	Explanation
1	Capability based	Assess the technical requirements that the ubiquitous computing service should have.
2	Ubiquity based	Assess to what extent a providing service is ubiquitous.

u-Transformation

Level of u-Transformation is used to assess the degree how the legacy technologies and services are transformed to the ubiquitous ones. Since preparing the concrete methodology to evaluate the degree of u-transformation in the companies or the organizations is in its very early stage, we focused only on evaluating personal objects and services which adopt ubiquitous computing technology. As assessing the level of u-Transformation should be aligned to the ultimate goals to propose the concept of ubiquitous computing technology, the assessing methodology must consider the goals. For example, verifying to what extent an object or service support natural interface, which is one of the primary goals of ubiquitous computing technology could be a good guideline to estimate the level of u-Transformation. Hence, we evaluate the level of u-Transformation according to the two goal-oriented dimensions – level of capability and ubiquity.

Location Based Services

Location-based services have been regarded as promising application in the near future. Satoh categorized the LBS as the two types of approaches: 'computing devices move with the users' and 'tracking systems equipped to a space'. The categories with some example projects are listed in Table. 3.

Table 3 - Categories and Example projects of LBS

Approach	Research and Projects	Reference
Mobile devices	HP's Cooltown project	Kindberg T. et al. (2000)
	Stuttgart Univ.'s NEXUS	Hohl F. et al. (1999)
Embedded tracking systems	Cambridge Univ.'s Sentient Computing project	Harter A. et al. (1999)
	VNC System	Richardson T. et al. (1998)
	LocARE(CORBA-based middle ware)	Lopez de Ipina D. and Lo S. (2001)
	MS's EasyLiving project	Brumitt B.L. et al. (2000)

Even though the methodologies to assessing location-based services have been introduced, most of them are limited to evaluate the performance of the system performance itself mainly based on the technical perspective, not on the perspectives of how those location-based services are near to the basic goal and principles of ubiquitous computing technology. Only a few considerations have been conducted to evaluate how the products and services has evolved or transformed as shown in Table 4.

Table 4 – LBS Evaluation

Researchers	Evaluation Item	Sys.
Maruyama et al. (2004)	Personal Tourism Navigation System	O
Burak and Sharon (2003)	Usage of Location Based System	O
Wu and Wu (2003)	Proactive Pushing Strategy	O
Rinner and Raubal (2004)	Location based Decision Support System	O
Pages-Zamora and Vidal (2002)	Position Estimate Accuracy	O
Markoulidakis et al. (2002)	User Experience	G

* O = Performance of Own System
* G = Performance of General or Other Systems

Level of Capability

Finding IT Capabilities with Literature Research and UT Capabilities with Focused Group Interview

We looked up the contents referred about capabilities of IT from all the articles published at the Communications of ACM Journal between 1994 and early half of 2004. As results, we found 294 terms and summarized the frequency of each term. From this IT capability list revealed in the previous step, we asked the experts to choose the capabilities that related with ubiquitous computing service using focused group interview.

We made up the questionnaire for the experts in ubiquitous computing area to analyze that these capabilities are how important to ubiquitous computing services practically. We added the terms such as invisibility, reconfigurability. Even though those terms were not shown in the Communications of the ACM, those have been introduced continuously as developing ubiquitous computing issues. We chose 121 project managers and professors who were involving in the projects of developing the ubiquitous computing appliances or services and sent them the questionnaire through e-mail. After all, we received 35 responses (return ratio = 28.9%).

We conducted the descriptive statistics and got the results as listed in Figure 2.

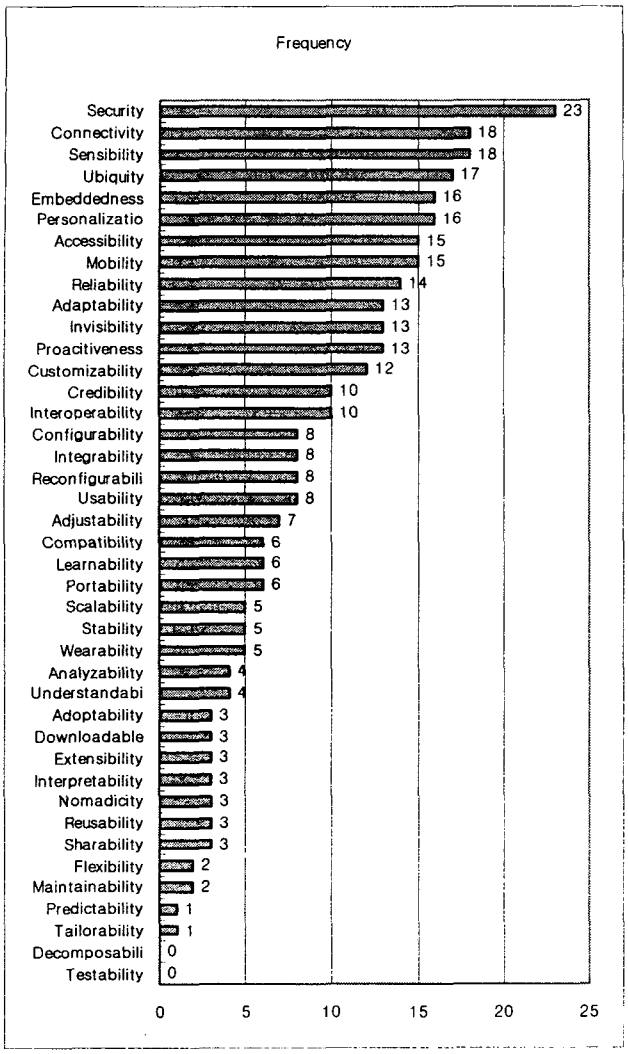

Figure 2- Descriptive Statistics about Capabilities of Ubiquitous Computing Service

Assessment by layer 1 model is mainly used to determined whether a service could be regarded as 'ubiquitous computing' service or not. This assessment is crucial because many ubiquitous computing services appeared in electronic markets may be actually not based on ubiquitous computing technology but just mobile or pervasive computing services. Moreover, layer 1 model is useful to advise a provider of a newly suggested service to find which capabilities or functionalities are omitted and hence need to be supplemented.

Evaluation Method

We could conduct an assessment with the persons who are specialties in the ubiquitous computing technology so that they can understand what the capabilities appeared in the statistics derived in this layer means. Seven Likert scale can be used for a certain IT-based service to identify to what extent the service can be regarded as ubiquitous computing service. The scale is represented as follows:

- Scale 1: The service definitely does not contain <a capability>.
- Scale 2: The service does not seem to contain <a capability>.
- Scale 3: It is hard to decide if the service contains <a capability>.
- Scale 4: The service a little bit contains <a capability>.
- Scale 5: The service seems to contain <a capability>.
- Scale 6: The service substantially contains <a capability>.
- Scale 7: The service definitely contains <a capability>.

For example, scale 7 for connectivity would be 'the service definitely contains connectivity.' Hence, the threshold value to decide if a specific service contains a certain capability is set to 3.0 in this paper. Using the scale and threshold value, the assessment procedure is as follows. First, give the point from 1 to 7 to each capability item shown in Figure 2, and then get weighted average value, which is the final score at layer 1. Second, by using a threshold (>= 3.0), which is the average of the total weight, each service is determined if the service is ubiquitous.

Level of Ubiquity

The weight for each criterion was same as using at layer 2-1. The definitions of '3 keywords' are shown at Table 5. The items of 3 keywords are shown at Table 6. The service grounded 3 keywords makes voluntary community of intelligent objects coexisting human and things, and is closely related to the realization of 'Community computing', the optimal service offering by case through each member's role play.

Table 5- Definitions of 3 keywords

3 Keywords	Explanations
Situation Sensing/Decision	Resolves the problems with sensing the various context and inferring the human intention.
Autonomic Computing	Meets the goal through the autonomous cure and re-structuring commissioned authority from human.
Self-growing Intelligence Engine	Has the aim the user's purpose or goal.

Table 6– Items to evaluate the level of ubiquity

Items	
User preference	Fault tolerance
User profile	Negotiation
User context	Trust
Location tracking	Self-control
Time tracking	Authentication
Identity tracking	Authorization
Entity tracking	Usability
Context reusability	Ease of use
Inferred context	Seamlessness
Service coverage	Response time
Learning	Scalability
Reasoning	Durability
Autonomy	Standardization

Automation	

Evaluation Method

Using this evaluation method, the level of ubiquity measures as follows:

First, give points from 1 to 7 to each service item; then multiply the weight of an item to know the final score of each. Now add all final scores according to the keyword, and divide them to the sum of all weights of a keyword. With this score, get the evaluated score for each keyword: autonomy, self-growing, and community computing. For the last step, multiply the weight of a keyword to the keyword's evaluation, add all, and divide it to the sum of weights of each keyword. This is the final score of the service. The example of this evaluation appears on the next section.

Example

Service Selection

To measure the level of u-Transformation, five actual services were selected from location announcing services using GPS-based context to high value added navigation services. According to the two categories, GPS and navigation, one of the services was chosen from GPS services, the remaining services from navigation services. The selected services for test are described in Table 7.

Table 7 - The selected services for Evaluation

Category	Products and Services	Service Description
GPS	**RoadMate Pro http://www.road-mate.co.kr**	- Backward Alarm Receiver - Road-danger Guide - Traffic Information Storage and Voice Guide - Place Register by User-Own
Navigation	**ALMAP NAVI http://www.almap.co.kr**	- Navigation - Overspeed Area Warning and Traffic Information Guide by Voice - Driving Simulation - Track-log Management
	I-NAVI http://www.inavi.co.kr	- Accident-Frequent Area and Safety Speed Block Voice Guide - Buzz for Overspeed Alarm when Over Assigned Speed - Real-Time Route Voice Guide - Near Facility Search - Frequent Visit Place Setup - Route Secession Alarm and Route Re-Setup
	Nate Drive http://drive.nate.com	- Route Guide using Voice and Map - Watch-Camera Location Guide using Cell-phone Screen and Voice - Real-Time Traffic Information - Information Gathering about Facilities Around - Restaurant/Travel Place Recommendation
	Mozen http://www.mozen.com	- Burglary Alarm and Trace - Fast-Route Guide, Real-Time Traffic Information, Danger-Area Alarm - Car Remote Diagnosis, Parking Location Alarm - Restaurant/Travel Place Recommendation

Evaluation Procedure

The domain experts are supposed to give the weight for location-based service to each item of ubiquity by observing each service. After the observation, the experts are asked to give the scores to each item of capability and ubiquity to evaluate those levels. Finally, interpret the scoring results of the assessments.

Results

Table 8 – Level of Capability

Items	Weight	RM	AN	IN	ND	MO
Security	6.97	1	1	1	2	2.3
Connectivity	5.45	2.3	3	3	2.7	4
Sensibility	5.45	2.3	2.7	2.7	3	3.3
Ubiquity	5.15	1	1	1	1.7	2
Embeddedness	4.85	1	1.3	1.3	1.7	2.3
Personalization	4.85	1	1.3	2	2.3	4
Accessibility	4.55	2	2.3	2.3	3	3
Mobility	4.55	2.3	3.3	3.3	4.3	3.7
Reliability	4.24	2	2.3	2.3	2.3	3
Adaptability	3.94	2	1.7	2	2.7	3
Invisibility	3.94	1	1	1.3	1.7	2
Proactiveness	3.94	1.7	2.3	2.3	2.7	3
Customizability	3.64	1.3	1.7	2	2.3	3.7
Credibility	3.03	2	2	2.3	2.3	3.3
Interoperability	3.03	1.3	1.3	2	3	4
Configurability	2.42	1	1.7	1.7	3	2.7
Integrity	2.42	1	1.3	1.3	2	2.3
Reconfigurability	2.42	1	1.3	1.7	2.3	2.7
Usability	2.42	1.7	2	2.3	3	3.7
Adjustability	2.12	2	2.3	2.3	2.7	3.3
Compatibility	1.82	1	2.3	2.3	3.3	2.3
Learnability	1.82	1	1.7	2.3	2	3.3
Portability	1.82	2.7	2.3	2.7	4	1.3

Scalability	1.52	2.7	3.3	3.3	3.3	4
Stability	1.52	3.3	3	3	3	3.3
Wearability	1.52	1.7	2	2	3	2.7
Analyzability	1.21	1	2	2.3	1.7	3
Understandability	1.21	2.7	3	3.3	3.3	4
Adoptability	0.91	1.3	2.7	2.3	3	3
Downloadable	0.91	1.7	2	2.3	3	2
Extensibility	0.91	1	2.7	2.7	3	2.7
Interpretability	0.91	1.7	2.7	2.7	2.7	3.7
Nomadicity	0.91	2	2.3	2.3	3	3
Reusability	0.91	1.7	2.3	2	3	2.7
Sharability	0.91	1	1	1	1.7	2.3
Flexibility	0.61	1	2.3	2	2.7	3.3
Maintainability	0.61	3	3	3	3.7	4.3
Predictability	0.3	1.3	2.7	2.3	3	3.7
Tailorability	0.3	1.3	3	3	2.7	3
Final Score		**2.9**	**3.54**	**3.79**	**4.65**	**5.43**

The results of the level of capability are listed in Table 8: RoadMate is 2.9, Almap Navi is 3.54, I-Navi is 3.79, Nate Drive is 4.65, and Mozen is 5.43. Since the features such as 'Traffic Information Storage' and 'Place Register by User-Own' that RoadMate has indicate the lower level of sensibility, proactiveness, and learability, RoadMate scores the lowest. On the other hand, since some of the features such as 'Car Remote Diagnosis' and 'Burglary Alarm and Trace' that Mozen has indicate the high level of 'Personalization' and 'Sensibility', Mozen stands on the highest place.

Table 9 - Level of Ubiquity

3 Keywords			Items	Services				
S	A	G		RM	AN	IN	ND	MO
7.67	1.33	1	Location Tracking	1.67	3	3.67	3.67	3.67
7	2	1	Time Tracking	1	2	2	3	3
6.33	2.67	1	Identity Tracking	1	1	1	1	2
6.33	2.67	1	Entity Tracking	1.67	2.33	2.33	2.67	3
4	3	3	Inferred Context	1	2.33	2.67	2.33	3.33
4	4	2	Authentication	1	1	1	1	2
3	4	3	Authorization	1	1	1	1.67	2
3	5	2	Response Time	2.33	3	3	3.33	4
3.67	4.67	1.67	Scalability	2.33	2	2.33	2.67	3
3.33	4.67	2	Durability	3.67	2.33	2.33	2.67	3.33
2.33	4	3.67	User Preference	1	1.33	1.67	2	3.33
1.67	5	3.33	User Profile	1.67	2	2.67	3	3.67
2	3	5	Reasoning	1	2	1.33	2.67	3
2.67	4.67	2.67	Autonomy	1.67	2	2.67	2.33	2.67
1.33	7	1.67	Automation	1.67	2.67	2.67	3	3
2.67	2.67	4.67	Negotiation	1	1.33	1.33	2	2.67
2.67	3.67	3.67	Trust	1.33	1.67	2.33	3	4
1	5.33	3.67	Self-control	1.67	1.33	1.67	2	3
1.67	5.67	2.67	Fault Tolerance	1	1.33	1.33	1.67	2.33
1	2.67	6.33	Context Reusability	1	2.33	2	2	3.33
2.33	4.33	3.33	Service Coverage	4	4.33	4.33	4	5
2.33	3	4.67	Learning	1	1	1	1	2.33
2.33	4.67	3	Usability	1.33	2.67	3	2.67	3.67
3.23	3.9	2.87		1.57	2	2.14	2.41	3.1
Final Score				**1.54**	**2.00**	**2.15**	**2.43**	**3.16**

Meanwhile, the evaluation results in terms of the level of ubiquity are shown in Table 9: RoadMate is 1.54, Almap Navi is 2, I-Navi is 2.15, Nate Drive is 2.43, and Mozen is 3.16. The scores of the items such as 'Location Tracking', 'User Preference', and 'User Profile' showed the gap of the level of ubiquity between RoadMate and Mozen.

Level of u-Transformation

Table 10 – Level of u-Transformation

	Capability	Ubiquity
RoadMate	2.90	1.54
Almap Navi	3.54	2.00
I-Navi	3.79	2.15
Nate Drive	4.65	2.43
Mozen	5.43	3.16
Threshold	3.00	N/A

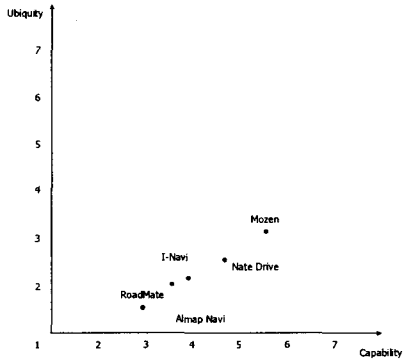

Figure 3 – Level of u-Transformation

As shown in Table 10 and Figure 3, since the level of capability of RoadMate (2.90) is less than the threshold ($\theta >= 3.00$), RoadMate was not regarded as a kind of ubiquitous service and hence was excluded for further assessment. Almap Navi and I-Navi provide the lower level of ubiquitous service than Nate Drive and Mozen. Nate

Drive runs on cell-based service and guarantees the higher level of mobility which is substantially required by the ubiquitous services. Since Mozen adopts intelligent services such as 'Restaurant/Travel Place Recommendation', 'Burglary Alarm and Trace' and 'Car Remote Diagnosis', higher level of security and ubiquity is doable.

Table 11 – LBS Service Description

Category	Services	Kinds of Service
GPS	RoadMate	GPS-based Simple
Navigation	Almap Navi	Navigation-based Simple
	I-Navi	Navigation-based Simple
	Nate Drive	Cell-based Immediate
	Mozen	Navigation-based Immediate

The selected services are re-classified based on the assessment results. As the level of capability and ubiquity, 'simple-' or 'immediate-' is given. We also give the category based on the location sensors: 'GPS-', 'Navigation-', and 'Cell-'. The re-classification service restuls are shown in Table 11.

Conclusion and Further Studies

In this paper, a methodology to assess the level of u-Transformation in the domain of location-based services was proposed. A two-phased approach is adopted to represent the assessment model: capability-based assessment as phase one and ubiquity-based assessment as phase two. One of the main contributions of this paper, to our knowledge, would be to firstly address the need of assessing u-Transformation to suggest the developing directions of ubiquitous computing services. The level of u-Transformation using the currently available services based assessment, not scenario-based assessment is given. Even though the level of capability and ubiquity is the main factor to explain the degree of u-Transformation, further research must be conducted to explain more concretely why the two levels are representative. Moreover, enlarging the areas of evaluating services other than location-based services to justify the methodology would be necessary.

Acknowledgments

This research is supported by the ubiquitous Autonomic Computing and Network Project, the Ministry of Information and Communication (MIC) 21st Century Frontier R&D Program in Korea (2003-2005).

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