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 providing services to a new service everywhere, every time, with any devices to gain more comparative advantages than the other typical services. This opportunity naturally requires a methodology to assess to what extent the legacy e-services are transformed to the uT-based services. However, research about assessing the level of u-Transformation has been still very few. Hence, this paper aims to propose a methodology for assessing the level of u-Transformation oriented by the teleology of ubiquitous services. A case study, GPS-based navigation services, is performed to show the feasibility of the methodology addressed in this paper.

1 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. E-Transformation has been defined as 'the transforming processes that occur in all area of the organization such as the way of transaction, organizational structure, culture and processes by the electrification of the overall processes in the organization with introducing IT and network technology to the organization under the digital environment' (Haeckel, 1999; Deise et al., 2000; Hammer, 2001). 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.

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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 example of the actually conducting Location Based Services.

2 Related Studies

2.1 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 service users with contextually relevant information. Ubiquitous computing technologies, therefore, that can be used to identify the user's current context and to recommend goods or services based on the context data, are well suited to current intelligent information systems.

Currently, researchers have proposed a variety of ubiquitous computing services. For example, in 2003, 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 Fig. 1, the services located in the lower left area of the figure are anticipated to be appeared shortly.

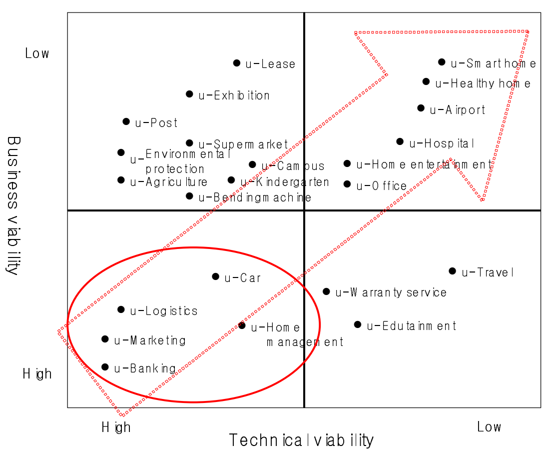

Fig. 1. Ubiquitous computing services

2.2 Location Based Ubiquitous Computing Services

Location-based services have been regarded as a 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. 1.

Table 1. Categories and example projects of LBS

Approach	Research and Projects	Reference
Mobile devices	HP's Cooltown project	Chen, H. and Tolia, S. (2001)
	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 2.

Table 2. LBS evaluation

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

2.3 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 3.

Table 3. Evaluation of ubiquitous computing systems and services

Authors	Content
Riekki *et al*. (2004)	'Level of Calmness' of ubiquitous computing systems
Scholtz and Consolvo (2004)	attention, adoption, trust, conceptual models, interaction, invisibility, impact and side effects, appeal, application robustness
Mankoff *et al*. (2003)	evaluated ubiquitous computing focused on a specific field, such as sensing systems
Bellotti *et al*. (2002)	address, attention, action, alignment, accidence
Friedman *et al*. (2001)	human welfare, ownership and property, freedom from bias, privacy, universal usability, trust, autonomy, informed consent, accountability, identity, calmness, environmental sustainability
Spasojevic and Kindberg (2001)	interference, efficacy, design implications
Quintana (2001)	accessibility, use, efficiency, accuracy, progression, reflectiveness
Richter and Abowd (2001)	quantitative: user logs qualitative: questionnaires, interviews, observations
Burnett and Rainsford (2001)	ubiquity/pervasiveness, invisibility, connectedness, context-awareness
Basu (2001)	speed, quality, efficiency, resilience to mobility, application performance after embedding
Dey (2001)	configuration, inference, distractions/nuisance, graceful degradation, personal information, ubiquity, evolution

2.4 Level of u-Transformation

Level of u-Transformation is used to assess to what extent 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 will focus only on evaluating the services which adopt ubiquitous computing technology. And the level of u-Transformation gives us the state of the ubiquitous computing technology development to handle the speed of present development properly and to predict the priority and speed of development. For these reasons, the level of u-Transformation should be assessed. For example, verifying to what extent an object or service support natural interface, which is one of the primary goals of ubiquitous computing, 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 as listed in Table 4. Based on the two assessments, level of u-Transformation (*LoUT*) is computed as (1):

$$LoUT = \begin{cases} 0, if\ LoC < \theta \\ \alpha LoC + (1-\alpha)LoU, if\ LoC \geq \theta \end{cases} \quad (1)$$

where $0 \leq \alpha \leq 1$, *LoC*, *LoU* and θ indicates level of capability, level of ubiquity and threshold whether the service is ubiquitous, respectively. Formula (1) shows that the purpose of this evaluation focuses on either LoC or LoU. α expresses to what extent LoC is more important than LoU in the assessment; if α increases, then the assessment is more focusing on how the legacy technologies and services are based on ubiquitous philosophy rather than focusing on estimating technical level, and vice versa.

Table 4. Two-layered ubiquitous service assessment

Layer	Assessment	Explanation
Infrastructure	Capability based	Assess the technical requirements that the infrastructure of the ubiquitous computing service should have.
Application	Ubiquity based	Assess to what extent the providing application of the service is ubiquitous.

3 Infrastructure Layer: Level of Capability

3.1 Finding IT Capabilities and UT Capabilities

We looked up the contents referred about capabilities of IT from all the articles published in the Communications of the ACM journal between 1994 and early half of 2004. As a result, 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 to what extent these capabilities are important to ubiquitous computing services practically. We added the terms such as invisibility, re-configurability to the IT capability list. Even though those terms were not shown in the Communications of the ACM journal, 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%). According to the two surveys, capabilities which could be related to ubiquitous computing functionalities are obtained as shown in Fig. 2. We adopted the frequencies of chosen capabilities in the answers to find the weight of each capability.

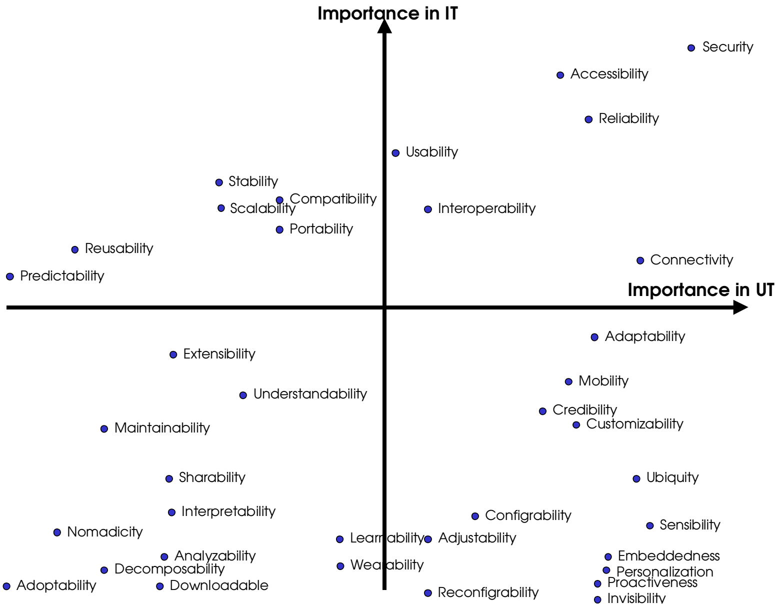

Fig. 2. Locus of capabilities

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

3.2 Evaluation Method

We conducted an assessment with the persons who are experts in the area of ubiquitous computing technology so that they understand what the capabilities appeared in the statistics derived in this layer means. Seven Likert scale is 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, equal or less than scale 3, 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 Fig. 2, and then get weighted average value, which is the final score at infrastructure layer. Second, by using a threshold (>= 3.0), which is the average of the total weight, each service is determined if the service is based on ubiquitous computing technology.

4 Application Layer: Level of Ubiquity

The weight for each criterion was same as using at application layer. The definitions of ‘three keywords’ are shown in Table 5. The items of three keywords are shown in Table 6. The service grounded the three 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. To get the weight of each item, the experts gave the weight of importance to each item and we averaged these weights.

Table 5. Definitions of three keywords

Three Keywords	Explanations
Situation Sensing /Decision	Resolves the problems based on sensing the context data and inferring the user’s intention.
Autonomic Computing	Meets the goal through the autonomous cure and re-establishes commissioned authority from the user.
Self-growing Intelligence Engine	Learns the user’s purposes or goals for the time being.

Table 6. Items related 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	

4.1 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.

5 Case Study

5.1 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

Table 7. The selected services for evaluation

Category	Products and Services	Service Description
GPS	**RoadMate Pro** (http://www.roadmate.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

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.

5.2 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.

6 Results

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 learnability, 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 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
omitted						
Final Score		**2.9**	**3.54**	**3.79**	**4.65**	**5.43**

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.

Table 9. Level of ubiquity

Weight of 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

7 Level of u-Transformation (LoUT)

Based on the capability-based assessment (LoC) and ubiquity-based assessment (LoU) as stated in Section 6, level of u-Transformation (LoUT) is estimated as shown in Table 10 and Fig. 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. In case of $\alpha = 0.5$, as shown in Table 10, 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 10. Level of u-Transformation ($\theta = 3.0$)

	LoC	LoU	LoUT ($\alpha = 0.5$)
RoadMate	2.90	1.54	n/a
Almap Navi	3.54	2.00	2.77
I-Navi	3.79	2.15	2.97
Nate Drive	4.65	2.43	3.54
Mozen	5.43	3.16	4.30

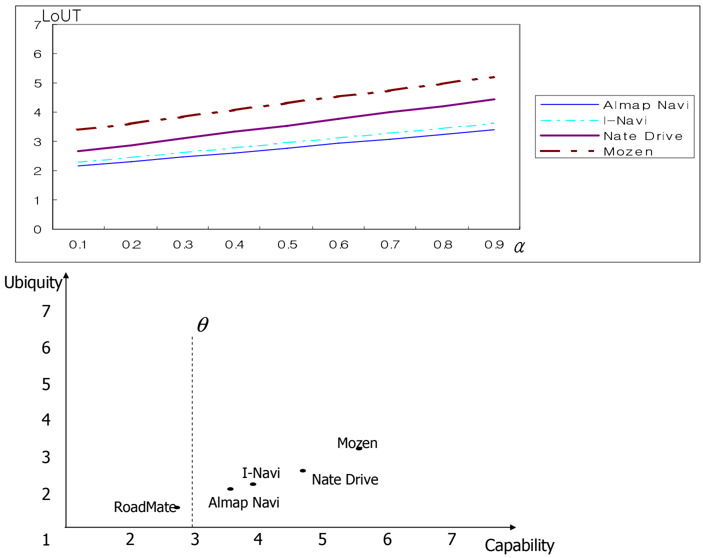

Fig. 3. Level of u-Transformation

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 results are shown in Table 11.

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

8 Conclusion

In this paper, a methodology to assess the level of u-Transformation was proposed. A two-layered approach is considered: capability-based assessment at infrastructure layer and ubiquity-based assessment at application layer. One of the main contributions of this paper, to our knowledge, is that the need of assessing u-Transformation for developing the ubiquitous computing services is firstly suggested. Level of u-Transformation (LoUT) 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.

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References

1. Bellotti, V., Back, M., Edwards, W. K., Grinter, R. E., Henderson, A., and Lopes, C.: Making Sense of Sensing Systems: Five Questions for Designers and Researchers. In: Conference of Human Factors in Computing Systems (2002) 415-422
2. Brumitt B.L., Meyers B., Krumm J., Kern A., Shafer S.: EasyLiving: Technologies for Intelligent Environments. In: International Symposium on Handheld and Ubiquitous Computing (2000) 12-27
3. Burak, A. and Sharon, T.: Analyzing Usage of Location Based Services. In: Conference on Human Factors in Computing Systems (2003) 970-971
4. Chen, H. and Tolia, S.: Steps Towards Creating a Context-Aware Software Agent System. HP Technical Report HPL-2001-231 (2001)
5. Cheung, W.K.-W.: e-Transformation Technologies: Case Studies and the Road Ahead - A Value Chain Perspective. In: e-Technology, e-Commerce and e-Service. EEE '04 (2004) 509-516
6. Deise, M.V., Nowikow, C., King, P. and Wright, A.: Executive’s Guide to E-Business: From Tactics to Strategy, John Wiley & Sons (2000)
7. Friedman, B., Kahn Jr., P.H., and Borning, A.: Value Sensitive Design: Theory and Methods. In: Tech. Report 02-12-01, University of Washington, Dec. (2002)
8. Harter A., Hopper A., Steggeles P., Ward A., and Webster P.: The Anatomy of a Context-Aware Application. In: Conference on Mobile Computing and Networking (MOBICOM'99) (1999) 59-68
9. Haeckel, S.H.: Creating and Leading Sense-and Respond Organizations, Boston, Harvard Business School Press (1999)
10. Hammer, M.: The Agenda: What Every Business Must Do to Dominate the Decade, Crown Business (2001)

11. Hohl F., Kubach U., Leonhardi A., Rothermel K., and Schwehm M.: Next Century Challenges: Nexus - An Open Global Infrastructure for Spatial-Aware Applications. In: Conference on Mobile Computing and Networking (MOBICOM'99) (1999) 249-255
12. Kwon, O.B., Kim, J.H., Choi, K.H. and Kim, C.S.: A Multi-Layered Methodology for Assessing Level of Ubiquitous Computing Services. GESTS International Transactions on Computer Science and Engineering (2005) 134-142
13. Lee, H.G., Kim, K.K. and Kwon, O.B.: The 1st Annual Report on the Ubiquitous Computing Services, MOST, Korea (2004)
14. Leem, C.S., Suh, H.S., Kim, B.Y., Park, N.: A study on e-Transformation effectiveness analysis with cases in manufacturing and retail industries. Production planning & control, Vol. 14. No.8. (2003) 798-809
15. Lopez de Ipina D. and Lo S.: LocALE: a Location-Aware Lifecycle Environment for Ubiquitous Computing. In: 15th International Conference on Information Networking (ICOIN'01), IEEE Computer Society (2001) 419
16. Mankoff, J., Dey, A., Hsieh, G., Kientz, J., Lederer, S., and Ames, M.: Heuristic Evaluation of Ambient Displays. In: Conference of Human Factors in Computing Systems, ACM Press (2003) 169-176
17. Maruyama, A., Shibata, N., Murata, Y., Yasumoto, K., Ito, M.: A Personal Tourism Navigation System to Support Traveling Multiple Destinations with Time Restrictions. In: 18th International Conference on Advanced Information Networking and Applications, Vol. 2. (2004) 18-21
18. Pages-Zamora, A. and Vidal, J.: Evaluation of the Improvement in the Position Estimate Accuracy of UMTS Mobiles with Hybrid Positioning Techniques. In: 55th Vehicular Technology Conference, Vol. 4. (2002) 1631-1635
19. Richardson T., Stafford-Fraser Q., Wood K., Hopper A.: Virtual Network Computing. IEEE Internet Computing, Vol. 2. No. 1. (1998) 33-38
20. Riekki, J., Isomursu, P., and Isomursu, M.: Evaluating the Calmness of Ubiquitous Applications In: 5th International Conference of Production Focused Software Process Improvement (PROFES 2004) Kansai Science City, Japan, 5-8 April (2004)
21. Rinner, C. and Raubal M.: Personalized Multi-criteria Decision Strategies in Location-Based Decision Support. Journal of Geographical Information Science, Vol. 10. No. 2. (2004) 149-156
22. Satoh I.: Location-Based Services in Ubiquitous Computing Environments. In: ICSOC 2003, Lecture Notes in Computer Science, Vol. 2910. Springer-Verlag. (2003) 527-542
23. Scholtz, J. and Consolvo, S.: Toward a Framework for Evaluating Ubiquitous Computing Applications," Pervasive Computing, Vol. 3. No. 2. (2004) 82-89
24. Weiser M.: The Computer for the 21st Century. Scientific American, Vol. 265. (1991) 94-104
25. Wu, S. and Wu, K.T.: Dynamic Data Management for Location Based Services in Mobile Environments. In: Seventh International Database Engineering and Applications symposium (2003) 180-189