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## Utilizing Spatial-data to Provide for U-Service Based on U-GIS

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### ABSTRACT

According to the changes of the city's paradigm, the demand on u-City increases rapidly. u-City has been built at 54 areas in Korea (as of May 2009). One of the important determinants of success or failure in the increasing of u-City is how to provide u-Services. Most current u-Services are Sensor Network-based monitoring services to manage urban infrastructure. u-GIS is one of fundamental requirements to implement 'any time and any where' u-Service which covers the essential meaningful term "ubiquitous". Hence, in this paper, we 1) describe the definition of the spatial awareness, 2) discuss how to converge (Spatial Embedding) among different spatial data : topographic spatial data, sensor spatial data, and more, 3) bring forth an advanced form of u-Service, 4) analyze the state-of-the-art u-GIS techniques.

**Keywords** : Spatial Awareness, Spatial Embedding, U-Service, u-City, U-GIS

### 요 약

도시의 패러다임이 변화하고 이에 따라 u-City의 수요가 급증하고 있다. 우리나라에서만 2009년 5월을 기준으로 54개 지역에서 u-City가 구축되고 있다. 이렇게 급증하는 u-City의 성패를 좌우하는 중요 요소 중 하나가 바로 u-City에서 제공하고자 하는 u-서비스라고 할 수 있겠다. 현재의 u-서비스는 센서네트워크를 기반으로 하는 도시 관리 위주의 모니터링 서비스가 대부분이다. 유비쿼터스의 본질적 의미인 '언제 어디서나'의 u-서비스를 구현하기 위해서는 공간정보의 활용이 필수적이다. 공간정보와 센서정보의 결합은 공간인지(spatial awareness)를 가능케 하여, 모니터링서비스에서 보다 나아가 공간분석이 가능한 서비스로의 발전을 도모할 수 있다. 따라서 본 연구에서는 1) u-서비스에서 spatial awareness는 어떤 의미 인지를 명확히 하고, 2) spatial awareness를 가능케 하기 위해 공간정보, 센서정보, 기타 정보들이 어떻게 융합 (Spatial Embedding) 되어야 하는지 논하고, 3) U-GIS를 기반으로 한 u-서비스 시나리오 4가지를 제안하고, 4) 현재의 기술개발 현황에 대해 분석해 보고자 한다.

**주요어** : 공간 인지, 공간 융·복합, 유비쿼터스서비스, 유시티, 유비쿼터스지리정보시스템

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## I. Introduction

The demand on Ubiquitous city based on cutting-edge IT technology increases rapidly as the society develops and the paradigm of the city changes. u-City has been built worldwide, for example, in USA (Lower Manhattan), Cologne, Germany (Media Park), England (Urban Tapestries Project), Malaysia (Multimedia super Corridor), Dubai, United Arab Emirates (Dubai internet City), Japan (Reed City), etc. In Korea, u-City also has been constructed very actively at 54 areas (as of May 2009) such as Seoul (u-Seoul), Pusan (u-Pusan), Daegu (u-Daegu), Incheon (u-IFEZ). u-Service is one of the important determinants of success or failure in the rapidly increment of u-City. Presently, USN (Ubiquitous Sensor Network) technology is used to provide u-Service in various fields such as public facilities management, street light control, environment information, transportation, medical science to security manufacture, distribution, and home-network [1]. USN is a sensor network technology in which its sensing functions are integrated to RFID, and communication is enabled in real time since networking is made available among them. As the core technology, USN has been studied and developed to collect the real time data on moving objects

scattered in various places. The USN is an important base technology of u-City, of course, but owing to the USN-based is used to a lot of u-Service that are centered around sensor and those networks has been developed. Therefore, most current u-Service has been developed to monitor and manage urban infrastructures in the city. It is not quite the same meaning as ubiquitous (u)-service because this term means ‘anywhere, anytime beyond the space and time’. In other words, USN- based service is useful to monitor the situation within the sensor coverage, but the service has limitations on making users understand the situation based on spatial context. This is due to the lack of spatial awareness functionality in the u-Service. U-GIS makes it possible to overcome those limitations. It enables to analyze spatial data along with sensing data in real-time. The spatial awareness provides a better and more advanced u-Service and it is one of the most critical goals for u-Service. Therefore, it is necessary to identify technical requirements to make a context-based spatial awareness possible in u-Service.

Hence, in this paper, we 1) describe the definition of the spatial awareness, 2) discuss how to converge (Spatial Embedding) among different spatial data : topographic spatial data, sensor symbolic spatial data, and more, 3) bring forth an advanced form of u-Service, 4) analyze the state-of-the-art u-GIS techniques.



Fig 1. The five goals of Ubiquitous Service[2]

## 2. Spatial Awareness

There are five goals[2] of ubiquitous service (u-Service), which are Availability, Transparency, Seamlessness, Awareness, Trustworthiness.

Availability means that a service can be offered regardless of need, state, preference of the user under any circumstances, and Transparency means the user has no need to recognize the use of the tools. Seamlessness is that a service is offered consistently in any kind of environment. Which means that the service should be offered without disturbance whether moving between the interior space and the exterior space or changing of

the device by the user. Trustworthiness means that the service and reliability of the information offered for user's situation must be guaranteed. Awareness means that a device extends the human sense of the surrounding environment.

Spatial awareness means a context-based awareness in space which includes living space, topography space, and so on. A person is aware of surrounding space using five senses. So that, one can find the way to the theater located within a complex building like COEX owing to such a spatial awareness.

Spatial awareness in u-Service expands the human's cognitive ability to understand the situation in space. If spatial awareness is possible, by virtue of overcoming the limits of human, a user can understand and analyze the space around the user in the area.

[Fig. 2] depicts the concept of spatial awareness. Spatial awareness is processed in two steps; one being spatial query and the other being spatial analysis. The spatial query and spatial analysis are done in context-based. The context describes circumstances like weather, traffic, user's position, speed direction, etc, which can be changed in various situations[3].

If the USN-based u-Service is provided along with spatial information-based U-GIS, the u-Service will serve context-based spatial awareness, one of the five goals of u-Service. To make spatial awareness possible, it is necessary to research how to converge sensor network data and spatial data.

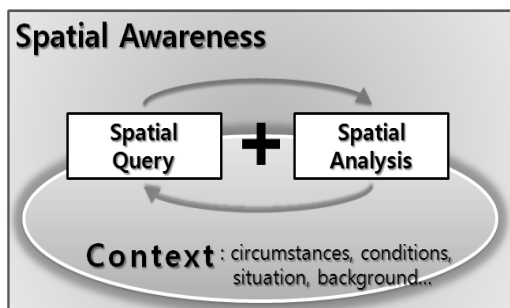


Fig 2. Context-based Spatial Awareness

### 3. Spatial Embedding

The convergence of sensor data and spatial data, called 'Spatial Embedding', is essential to make possible spatial awareness in u-Service. [Fig. 3] shows the concept of Spatial Embedding. Real-time monitoring data from GeoSensors and indoor/outdoor 2D&3D Geospatial data should be treated together. Methods of Spatial Embedding will be introduced in this section.

Nationwide base spatial data in Korea are Digital Map ver2.0 and National Framework Data. Digital Map ver2.0 has 104 layers according to 8 heads such as traffic, building, topography, etc. National Framework Data has 8 main layers such as cadastre, facility, administrative district, etc, each layer includes sub-detail heads.

As National Framework Data has more detail attributes than Digital Map ver2.0 do, spatial analysis is feasible for various fields. The National Framework Data and other spatial data such as underground facilities, CCTVs, police office, and so on can be used in u-Service. According to the purpose of service, statistics data such as population, culture, crime rate, etc, can be utilized as attributes data.

USN connects various sensors with wire/wireless

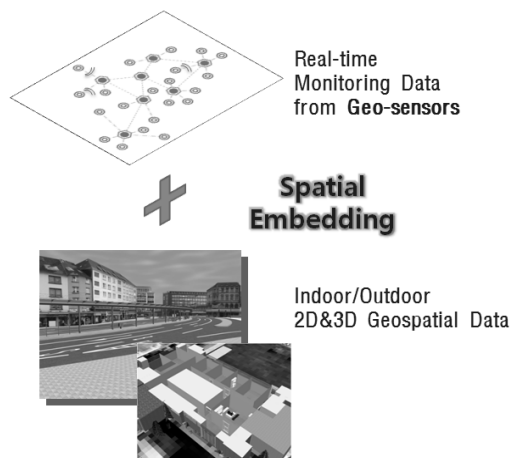


Fig 3. Spatial Embedding with Sensor Data and Geospatial Data[4]

network infra installed largely to gather context-based data, and links the detected circumstance data to service applications servers [5]. Many sensors sensing the temperature, the humidity, the intensity of illumination, the water quality, ozone, and more have been developed. It is important to utilize the sensing data directly or indirectly with spatial data using ‘Space Layer Convergence’ method to provide u-Service based on the geographical context

### 3.1. Space Layer Convergence

To develop spatial awareness, it is necessary to converge of sensor networks information and spatial information (Spatial Embedding).

[Fig. 4] illustrates the concept of Spatial Embedding in Multi-Layers Spatial Model[6].

In this figure, the real world can be represented in different space such as topographic space, sensor space, wiring space, waterworks space and so on. Each space representation, called Space Layer, is separated by subject and is managed in separated state. Indoor/Outdoor Topographic Space Layer is the most important basic

layer to offer u-Service based on geographical space (geospatial information). Indoor/Outdoor Topographic Space Layer represents the indoor and outdoor environment.

The Indoor Space Layer represents indoor space such as corridor, room, floor, etc. In case of outdoor, this Space Layer represents outdoor space such as road, building, water, vegetation, etc. Sensor network is described as Sensor Space Layer which is created by sensor’s types. Also, other additional Space Layers can be generated if necessary.

Many forms of Spatial Embedding are attainable in accordance with combination of Layers. In such cases to offer Public Area Security Monitoring Service and Search for Lost Child Service, it is possible by combining the following layers: Outdoor Topographic Space Layer, CCTV/RFID Sensor Space Layer, and more. Water Supply Facilities Management Service needs the combined Space Layers including Water Sensor Space Layer, Linkage Facilities Space Layer, Topography Space Layer, and more. The convergence of spatial data and sensor network data throw opens the door to spatial analysis based on context-based spatial awareness. This enables critical infrastructure analyses[7].

Many researchers have been interested in developing methods to make the convergence of sensor data and spatial data. The following section describes and analyses two developed methods which are N-partite graph model proposed by Kolbe[6] and U-GIS Convergence DB Engine developed by ETRI (Electronics and Telecommunication Research institute)[8].

#### 1) N-partite graph model

The connection among different Space Layers such as Building Space Layer, Sensor Network Space Layer, Road Space Layer, Water Supplies Space Layer and so on, is very important for the linkage analysis of space. Hence, Kolbe proposed N-partite graph model which links among different Space Layers topologically.

First, the principles of Poincaré duality[9] was used to represent the topological relationships among spatial

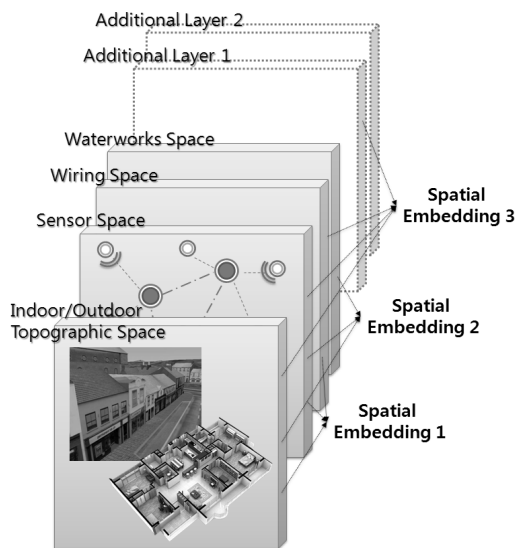


Fig 4. Concept of Spatial Embedding (modified Kolbe’ s Multilayer combination)[6]

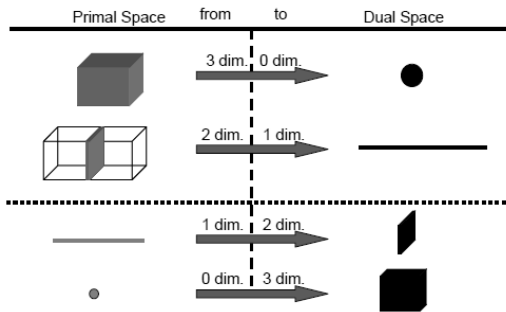


Fig 5. Principles of Poincaré duality[6]

objects in a Space Layer. [Fig. 5] explains the Poincaré duality. A 3D spatial object (3-dim) in Primal Space is transformed to a node (0-dim) in Dual Space. The sharing face (2-dim) between 3D objects in Primal Space is transformed to an edge (2-dim) in Dual Space. With the same principle, 1D and 0D objects in Primal Space are transformed into 2D and 3D objects in Dual Space.

The dual graph is called as Node-Relation Structure (NRS)[10] that uses partial duality to transform only 3D and 2D objects in Primal Space into 0D and 1D objects in Dual Space. The NRS, a network representation, represents the topological relationships among 3D objects in the Space Layers which are adjacency and connectivity relationships.

[Fig. 6(a)] shows the connectivity relationships among the 3D objects in a building such as rooms and corridors in Building Space Layer using the NRS. The dual graph in [Fig. 6(b)] represents the connectivity relationships among RFID sensor coverage (symbolic space) in Sensor Space Layer. [Fig. 6(c)] illustrates how to converge Space Layers using N-partite graph model. In the N-partite graph model, rooms and sensor coverage are mapped to nodes and the connectivity relationships among rooms and sensor coverage are mapped to edges (solid line). Building Space Layer can be connected to Sensor Space Layer through joint-state edges which are drawn by dashed lines. In more detail, room 1, 4, 6 are included in sensor coverage A. Node A, which represents sensor coverage A, is connected to node 1, 4, 6

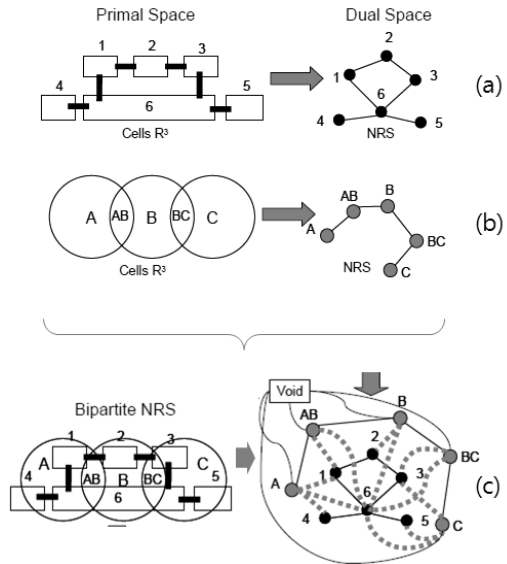


Fig 6. Simple example for modeling building space by using bipartite graph[6]

represented room by dashed lines (joint-state edges). The joint-state edges represent that if a person is in coverage A detected by sensor positioning technique such as RFID Reader, the person is in either room 1, 4, or 6.

[Fig. 7] is N-partite graph Data Model described by UML diagram that represents the connectivity relationships among space objects in Space Layers and the joint-state relationships among different Space Layers. Space Topology Object represents the connectivity relationships among 3D objects in a Space Layer using the NRS, and each Space Layer is joined together through n-partiteRelationObject represented by edges.

## 2) U-GIS Convergence DB Engine

U-GIS Convergence DB Engine developed by ETRI stores, manages and analyzes various GeoSensor data and spatial data. The U-GIS Data Convergence Query/Storage Management System in the DB Engine offers Real-time convergence control function and provides a function to keep track GeoSensor's historical data. The

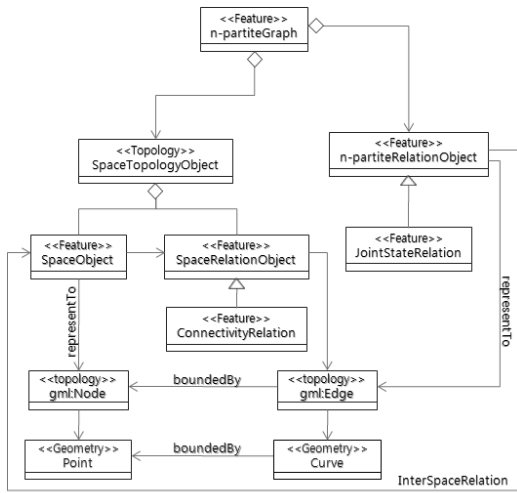


Fig 7. N-partite graph Data Model[11]

U-GIS Data Convergence Analysis System provides spatial-temporal analysis and time series analysis.

[Fig. 8] shows one example of U-GIS Convergence Queries using two separated DB servers which are GeoSensor Network Edge Server and GIS DBMS. This is a location based query to select GeoSensors (from GeoSensor Network Edge Server) located with factory areas (from GIS DBMS), when the GeoSensor’s CO density is over 8ppm. In this U-GIS Convergence Query, the results are given by sensor node locations, factory names, density of CO and factory areas. This method is one way to query sensor data and spatial data at once using geometric computations.

### 3) Comparative analysis

There is a different approach to converge Space Layers between N-partite graph model and U-GIS Convergence DB Engine. In N-partite graph model, the joint-state relationships among different Space Layers (sensor, building, road, facility, etc) are defined by a topological point of view. On the other hand, U-GIS Convergence DB Engine is to converge Space Layers by a geometrical point of view.

The following is an example of convergence between

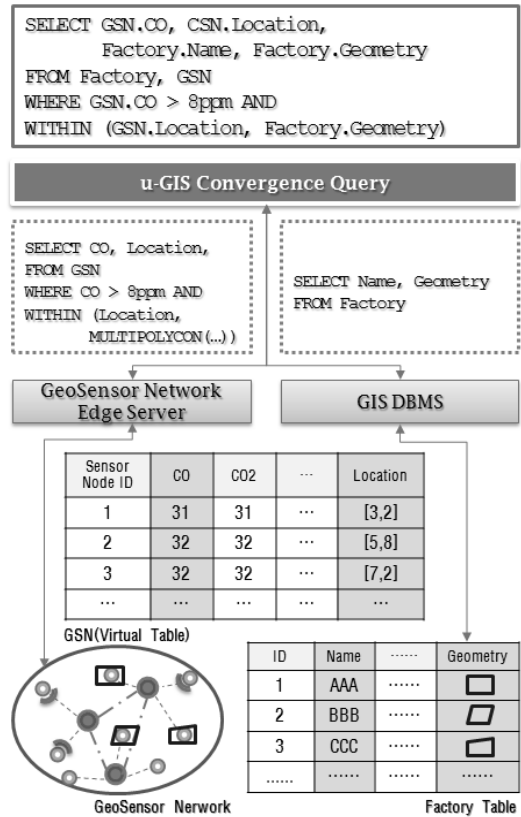


Fig 8. Example for Spatial Embedding query of U-GIS data[8]

Building Space Layer and Sensor Space Layer in an emergency situation when the outliers of sensor data are detected. In N-partite graph model, Nodes (3D objects in the real world such as room) in Building Space Layer can be searched by joint-state edges which connect to the outliers nodes (sensor nodes) in Sensor Space Layer. In U-GIS Convergence DB Engine, the rooms in the building including the detected sensor outliers are searched by geometric computations using building’s geometric data, sensor’s location data. In other words, due to the setting of the query condition about sensor and building together, the rooms associated with the detected sensors are searched from two different DB.

The efficiency of the two methods would be different

according to how to use them in u-Services. Since N-partite graph model is the form that different Space Layers are connected topologically, the connectivity relationships among the Space Layers can be defined easily. Therefore, the inter-linkage analysis for all Space Layers that were connected to the specific area where the event occurred would be very efficiently possible. As the U-GIS Convergence DB Engine queries several Space Layers at a time, spatial objects included in the spot where the specific event occurred would be searched very rapidly from each Space Layer. The Spatial Embedding methods such as N-partite graph model developed by Prof. Kolbe and U-GIS Convergence DB Engine developed by ETRI are used differently according to the purposes of u-Service. These kinds of techniques are very important to implement Context-based spatial awareness in u-Service.

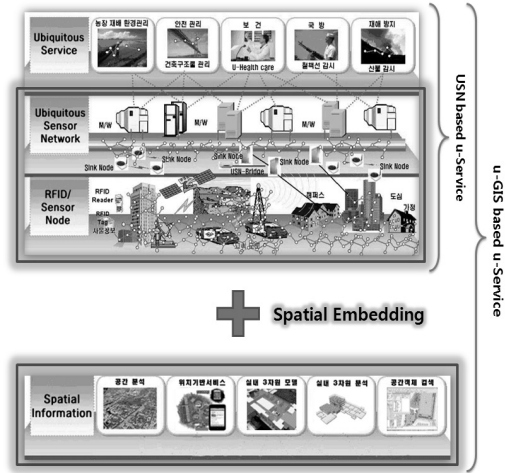


Fig 9. Concept of U-GIS based u-Service (modified original figure)[13]

#### 4. u-Service based on U-GIS

##### 4.1. The developed scenario of u-Service

Utilizing U-GIS to which the concept of Spatial Embedding is applied, it is possible to make Context-based spatial awareness in u-Services.

[Fig. 9] is the service concept map in which the u-Service based on U-GIS is provided through the combination of sensor network data and spatial data.

This study proposes service scenarios on four u-Services based on U-GIS, which include Water Supply Facilities Management Service, Public Area Security Monitoring Service, Intelligent Bicycle Use Service[12] from Core Research II and U-Air Pollution Management Service[14] from Core Research IV in the U-Eco City R&D Project.

##### 1) Water Supply Facilities Management Service

In the current water supply management u-Service, the sensors which detect the levels of water quantity and pollution are installed on main positions. If outlier data are detected, the positions are displayed on the

system and the sensing data are sent to the system managers to deal with the situation. However, in order to provide spatial awareness-based u-Service, as seen in [Fig. 10], several analysis steps should be included in the u-Services. The improved scenario of u-Service is as follows:

- Sensors that can detect the levels of water leakage and quality are installed on water supply pipes.
- Sensors collect data about the water quality regularly to decide whether the water quality is under the expected standard or not and to send the collecting data to u-City Management Center.
- Sensors measure the amount of water that passes through a specific section of water supply pipes per unit time and then send the data on the level of water leakage to u-City Management Center.
- If the water pollution level or the pressure level do not meet the requirements, u-City Management Center which monitors the system recognizes the situation.
- The location where water leak has occurred is detected and the amount of water leak is calculated using the water pressure data collected by sensors.
- The area which is likely to be damaged by water leak is analyzed. (For example, the residential and industrial area which is related with water leak are defined.)

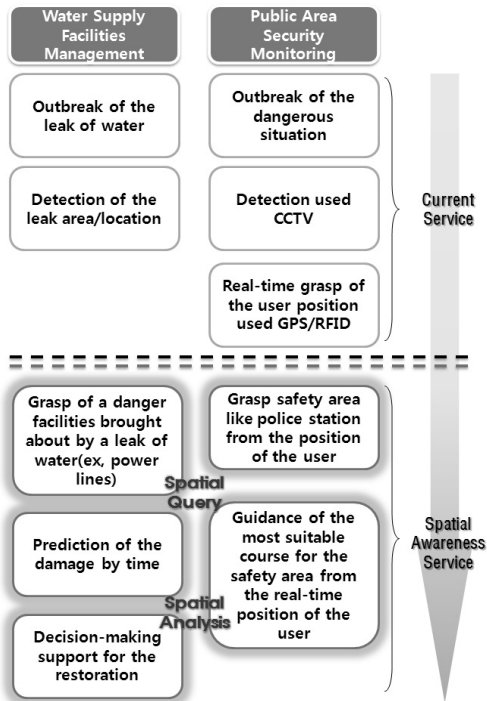


Fig 10. Two Examples of u-Service: Water Supply Facilities Management Service, Public Area Security Monitoring Service

- From the results of the analysis, some dangerous facilities are shut down and the damage by water leak is restored. The related data is provided to people who may be affected.
- A warning message and data about the status of water pollution and water leak is disseminated through the internet or mobile phones if needed.
- Real-time simulations are displayed through 3D GIS visualization.
- Providing real-time information through mobile phones to affected persons helps them to make the decision on what is needed.

### 2) Public Area Security Monitoring Service

As seen in [Fig. 10], in the current public security service, a lot of CCTVs are installed and real-time

monitoring for emergency can be performed through having wide camera coverage. Furthermore, a situation is analyzed automatically by intelligent CCTV. There is, however, a limitation in current service. If a user is out of a CCTV coverage, the user's location is not detected. In this case, the service should be spatial awareness-based u-Service to provide users with some information to guide to safe places through mobile devices according to user's situation. The following is a scenario for spatial awareness-based U-Services.

- A lot of CCTVs with voice communication devices are installed to offer communications with u-City Management Center through these CCTVs.
- RFID Readers are installed to get the location when a person is out of a CCTV coverage.
- When someone is under an emergency situation, the person reports the situation to u-City Management Center using a voice communication device installed in CCTVs.
- u-City Management Center keeps track of the situation through CCTVs.
- Real-time keep track of user's location. (For example, when a person is out of a CCTV coverage, the way such as Search For Lost Child Service in Haeundae which employs RTLS can be used.)
- Emergency facilities around a user's location are identified immediately and real-time analysis is performed automatically.
- u-City Management Center sends users information to guide safe places or police stations nearby to users' mobile device.
- The emergency organization dispatches rescuers to handle the situation.

### 3) Intelligent Bicycle Use Service

The current bicycle u-Service is to manage bicycles rather than to provide users with conveniences. In other words, this service has focused on bicycle's status and parking location such that it may not be sufficient for users. The Bicycle service using spatial information will be able to provide more developed service. In order



words, this service will give a route guidance which contains public transportation information. [Fig 11] shows the improved scenario for the GIS-based U-Services.

- Users can access the bicycle service system using an RFID and the ISO 29145 wireless communication system. After the process, users can borrow a bicycle.
- Bicycle rental information is sent to the system through wire/wireless networks along with information on the number of bicycle used and the distance covered.
- The fastest route guidance for user's destination is provided.
- Depending on the user's purpose, information a return place, bus stops, and places of interest are provided.
- If bicycles are put on wrong places, the location data

is obtained from GPS or local wireless area network and the bicycles are managed efficiently.

- Sensors which are installed on bicycles inspect main parts of bicycles regularly.
- If users use this U-Service, they can transfer to public transits effectively after obtaining the estimated arriving times of bus and subway and the optimal routes from the bike stations to the public transit stations.

#### 4) Air Pollution Management Service

The current air pollution management service monitors air pollution materials and provides density and size of the contaminated area. In the improved service, atmospheric pollutant perception and the distribution relative to time would also be available. This assists managers to plan locally as seen in [Fig. 11].

- Sensors which can inspect the air conditions are installed in living spaces.
- Collected data about carbon monoxide, ozone, yellow dust, waste gas, temperature and humidity are sent to the u-City Management Center.
- The movement pattern of air pollutants is analyzed from collected data about air pollution.
- The amount of generation and pattern of air pollutants are analyzed along with geographic data in real-time. Therefore, the current and expected damaged areas are analyzed.
- People are informed of the information from large electronic displays or mobile devices.
- In case that the air pollution affects people, main facilities send this information to related departments in real-time and inform people of the situation via large electronic displays.

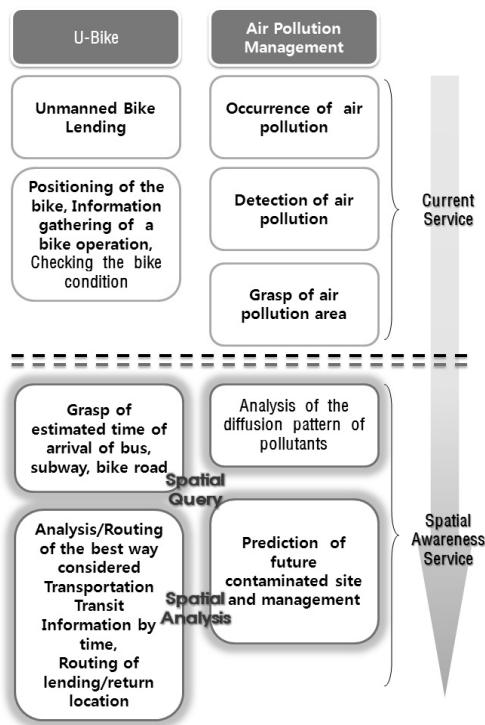


Fig 11. Two Examples of u-Service: Intelligent Bicycle Use Service, Air Pollution Management Service

#### 4.2. Analysis of the present status of technology development

Some researches about U-GIS are under way in the Korean Land Spatialization Group (KLSG)[15]. The

Intelligent Urban Facility Management is in progress of Core Project III of KLSG. The objective of the research is to commercialize techniques monitoring the ground/ underground facilities based on GIS and USN.

The next is the comparative analysis on the current U-GIS technology development status and describes a scenario that spatial awareness is possible. Later, we discuss on further studies.

[Fig. 12] shows a comparison between the developed

u-Service scenario of ‘Water Supply Facilities Management Service’ and ‘Intelligent Urban Facility Integration Management Application Technology Development’ in Core Project III of KLSG. Each unit technology can be mapped to each scenario step. First, at the Ground Facilities Management System, there are many technical developments for the detection of water leaking areas such as setting the sensor on lampposts and the construction of ground facilities management server

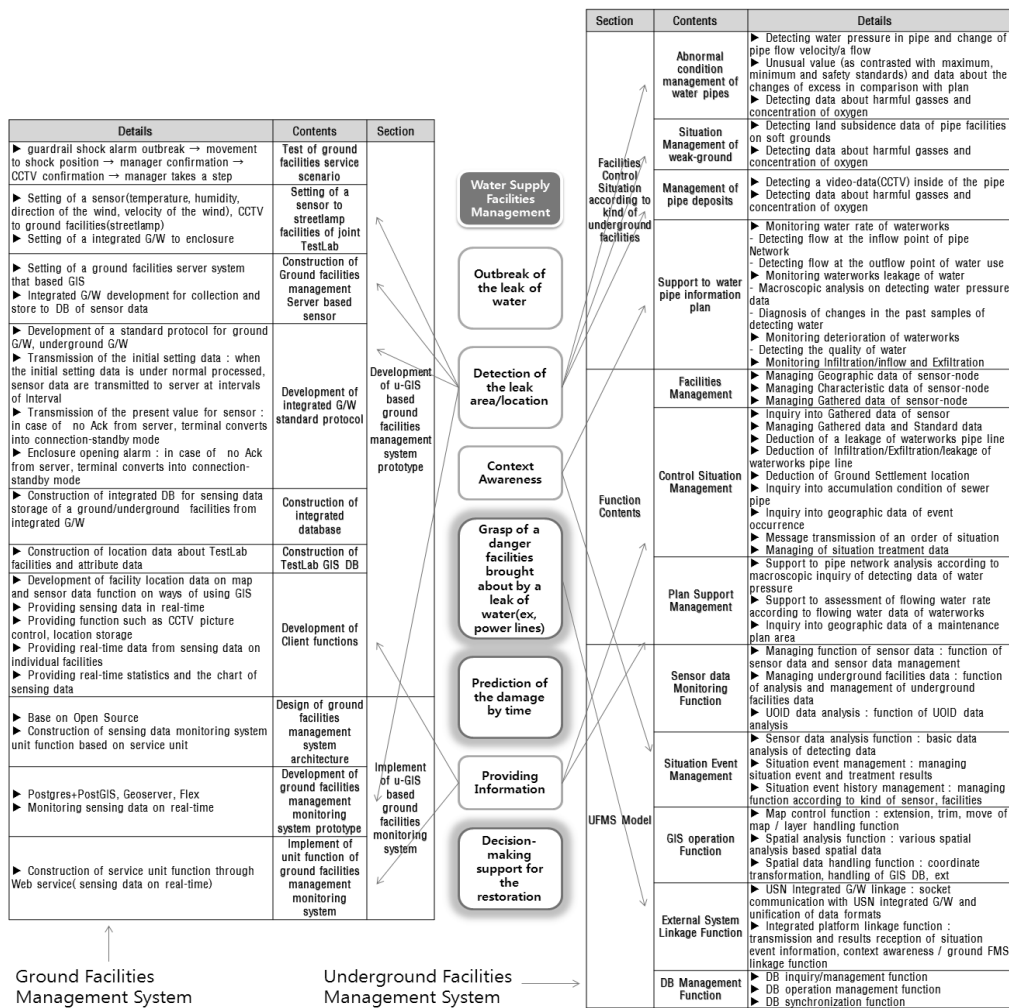


Fig 12. Matching between ‘U-GIS based scenario’ and ‘current technology’ about facilities management u-Service[16]

based on sensor and a standard protocol development to transmit the sensor data. Also, there are technical developments in order to provide information such as facilities location data and sensor data management function, real-time information of sensor data, web service function, statistical data and chats which utilizes the GIS to managers and citizens. In the Underground Facilities Management System, there are technical developments for detecting the water leakage area and data transmission such as running water/leak-ratio/water quality monitoring and ground subsidence detecting. As technical developments for context awareness is provided, a macroscopic interpretation based on collected data, changed data tracking, and handled the situation data are being developed.

As discussed above, technical development for detection and context awareness through the sensor data is in progress. Also many techniques for giving information are being developed. Technical development for detection and context awareness are active. On the contrary, the study about spatial analysis that is linked to spatial data is insufficient. There are spatial analysis functions used GIS operation functions, but spatial analysis techniques are not enough. It is required for technical developments to link to different Space Layers.

## 5. Conclusion

The paradigm of city is moving from a modern city that goals to maximize economic profits than quality of life to a high-tech/natural regression city. A city would be developed as a high-tech green city that is equipped with environment-friendly, high-tech technology, better citizen convenience, quality of life, and economic profit. Currently, u-City has been developed as a form of high-tech city actively. At this time, what we should keep in mind is the essence of u-City. u-City should be able to offer citizens the ‘anywhere and anytime’ service to maximize citizens’ convenience and quality of life. Accordingly, ‘What services are offered to citizens in u-City?’ is the very important issue. Up to

now, u-Service has been advanced in terms of managing the city. As a result, u-Service focuses on monitoring the city intelligently; it is developed in the situation based on sensor data. This is, however, not enough to call ‘anywhere, anytime’ u-Service due to the lack of understanding of spatial information. Additionally, it brought about lack of user (citizen)-oriented services that are important [17] in u-City.

Future u-Service should be advanced to possible convergence analysis between spatial data and sensor data. Then, the city manager may predict the changes of the situation spatially that occur at facilities; the citizen may be offered the results of analysis of surrounding space around user’s location as service. This service is dependent on time. As u-Service is offered based on individual’s context, u-Service would be citizen-friendly and interactive that enables citizens to feel as if they dwell in u-City.

To construct abovementioned u-City, in this study, we raised a question about the current direction of u-Service, suggested the technical requirement called Spatial Embedding which helps u-Service based on the essence of ubiquitous, presented the developed scenario of u-Service, and finally analyzed current technical development to bring out necessary technical elements in future.

As a foundation research for application of Spatial Embedding to u-Service, this study focused on understanding existing problems and demands, and on analyzing the present status. Therefore, this study has limitations on fully implementing a practical system and on proposing new Spatial Embedding technology. Hereafter, technical studies for application of Spatial Embedding to u-Service is necessary in the future.

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## References

- [1] Gyeonggi-do, Seongnam City, Korea Land Corporation, 2006. 1, "The Report of Constitutional Directions of pangyo, Seongnam U-City".
- [2] Wikipedia, Ubiquitous service, [http://en.wikipedia.org/wiki/Ubiquitous\\_service](http://en.wikipedia.org/wiki/Ubiquitous_service)
- [3] Li, Ki-Joune, 2007.10, "Geographic Context-Awareness for UBGI", 2007 conference of Geographic Information System Association Of Korea. pp. 3-18 (16page)
- [4] Lee, J, 2009.4, "Construction of u-City by u-GIS", 2009 conference of Geographic Information System Association of Korea.
- [5] Jeon, Ho In and Jung, Seong-hun and Kim, Young-bae and Kim, bum Joo and Baek, Jun Sun, 2005. 7, "The study of core technology for u-City", Journal of communications and Networks, Vol. 22, No. 7, pp. 91-126 (36pages).
- [6] Becker, T., Nagel, C., Kolbe, T. H., 2008, "A Multilayered Space-Event Model for Navigation in Indoor Spaces", 3D GeoInfo-information Sciences, In: Lecture Notes in Geoinformation and Cartography-3D Geo-Information Sciences, pp. 61-77
- [7] Kim, Eun Hyung, 2009. 4 "The conceptual information model for sensor-based urban facilities management -focused on urban ground and underground facilities-", The Journal of GIS Association of Korea, Vol. 17, No. 1, pp. 79-87
- [8] Korean Land Spatialization Group, 2009, "The first-phase study presentation : 5-1 core project, u-GIS Spatial Information Processing and Management Technology Development".
- [9] Munkres, J. R., 1984: Elements of Algebraic Topology, Addison-Wesley, Menlo Park, CA
- [10] Lee, J., 2004: 3D GIS for Geo-coding Human Activity in Micro-scale Urban Environments. In: M.J. Egenhofer, C. Freksa, and H.J. Miller (Eds.): GIScience 2004, Springer, Berlin, Germany
- [11] Korean Land Spatialization Group, 2009, "4-2 core project, The first-phase study report : Spatial data model and application system".
- [12] U-Eco City R&D Center, 2009, "U-Eco City R&D Center, Report Year 2 (U-Space Construction Technology, 2 core research)".
- [13] Jeon, Ho In, 2007, "The study of core technology for public /private u-City service", TTA Journal, Vol. 2007, No. 112.
- [14] U-Eco City R&D Center, 2009, "U-Eco City R&D Center, Report Year 2 (U-Eco City Test Bad Construction, 4 core research)".
- [15] Kim, Hyong-Bok, 2008. 6, "A way of Building u-GIS based u-City", Geographic Information System Association Of Korea, 2008 joint conference, pp. 293-297
- [16] Korean Land Spatialization Group, 2009, "The first-phase study presentation : 3-2 core project, Intelligent Urban Facility Integrated Management System Development".
- [17] Kim, Junghoon and Yi, Misook, 2007. 4, "A Study on Current Issues for the Realization of u-City", The Journal of GIS Association of Korea, Vol. 15, No 1, pp. 1-14 (14pages).

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