iKaaS Data Modeling: A Data Model for Community Services and Environment Monitoring in Smart City

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Abstract— Intelligent Knowledge as a Service (iKaaS) is an ambitious project aiming at integrating sensor management using Internet of Things (IoT) and cloud services by employing sensor data. The platform design covers self-healing functions based on self-awareness as well as basic functions such as inter-cloud, security/privacy management, and devices and data management. From the viewpoint of application development, ontology sharing is the most important to integrate services. This paper, the first step towards ontology sharing, defines the iKaaS data model as one that integrates data models used in all applications in the project. The data defined in the iKaaS data model is converted into RDF format and stored in the RDF database. The reasoning mechanism in semantic web allows the semantic integration of data and applications.

The iKaaS project is developing a prototype community service, town management and healthcare, in Tagonishi's Smart City. Presenting the iKaaS data model for these said services, this paper emphasizes the necessity of higher contextual awareness to achieve the goal of a better-fitted personalization for the individual.

Keywords— Smart City; Sensor Network; Community Service; CityGML; Data Model; Context-Awareness

I. Introduction

Internet service is shifting rapidly from a system centered to a personalized service. Personalization has been achieved through modeling user preference and behavior. One can see this from a user clustering from a purchase history and location-based services identifying a user's location by GPS. But such services are based on the general user model ignoring user's specific context. Future Internet service is expected to achieve further personalization by modeling user's contextual preference.

Context awareness has been studied as a theory of rational agent in the field of artificial intelligence[1], whose applications were limited to the command and control in army operations, robot manipulation in space, and etc.[2] However, currently application areas are expanding to everyday services.

To support this personalization trend, Internet service subscription environments are rapidly gaining portability because of the continuing deployment of ubiquitous services in both dimensions of mobility and pervasiveness. Mobility, which is achieved by carrying mobile terminals, guarantees service accessibility at any time and from any place. Pervasiveness improves service accessibility by removing terminal dependency. So far, ubiquity has been achieved by enhancing mobility where specific terminals such as mobile telephones and terminals can be connected to the Internet at any time and from any place. In the future ubiquitous society, in which computers and sensors are distributed in an environment, ubiquity through pervasiveness will be emphasized to provide device-independent services: restaurant menus displayed with a touch panel terminal, tourist information provided at information kiosks in a railway station, and etc.

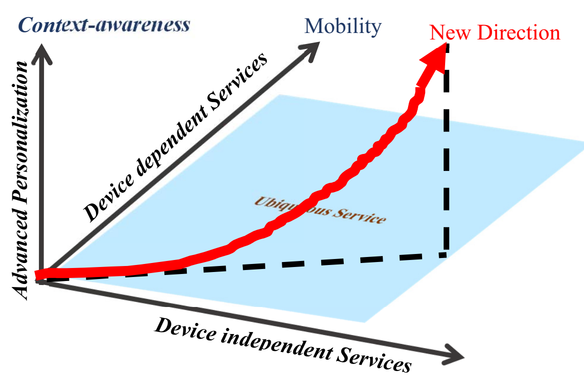

Figure 1 Context-awareness and ubiquity

Mobility and pervasiveness are the essential concepts of defining ubiquity. Internet of things is a system technology enabling ubiquitous service, including device, wireless, network, cloud, data and service management. Figure 1 shows the expected growth of context-aware personalized services based on ubiquity.

The basic context is described by geospatial and temporal information. Since iKaaS project is developing a prototype service in town management and healthcare in the smart city environment deployed at the Tagonishi area in Sendai, this paper presents the city data model in conjunction with other related data models in iKaaS applications.

This paper is structured as follows: Section II reviews the latest movement in standardization and existing projects. Section III introduces community services under consideration and presents the iKaaS data model. Section IV shows the use cases of iKaaS application. Section V concludes this paper.

II. RELATED WORKS

A. Movement of the Standardization

As a standard for geospatial description, Open Geospatial Consortium (OGC) has issued an information model for the storage and exchange of 3D city objects called the CityGML[3]. It defines the classes and relations for the most relevant topographic objects in cities and regional models with respect to their geometrical, topological, thematic, and appearance properties.

CityGML defines nine thematic modules and application domain extensions (ADEs). ADEs are defined according to the application goals. The thematic modules in CityGML and ADEs using CityGML are shown in TABLE I.

TABLE I. CITYGML THEMATIC MODELE AND ADES USING CITYGML

Item	Outline	States
CityGML thematic module		
Relief	Representation of the terrain in a city model	Published
Building	Thematic and spatial aspects of buildings, building parts, building installations, and interior building structures	Published
Tunnel	Representation of thematic and spatial aspects of tunnels, tunnel parts, tunnel installations, and interior tunnel structures	Published
Bridge	Thematic and spatial aspects of bridges, bridge parts, bridge installations, and interior bridge structures	Published
Water body	Thematic aspects and 3D geometry of rivers, canals, lakes, and basins	Published
Transportation	Representation the transportation features within a city, for example roads, tracks, railways, or squares	Published
Vegetation	Representation of vegetation objects	Published
City furniture	Immovable objects like lanterns, traffic signs, advertising columns, benches, or bus stops	Published
Land use	Representation of areas of the earth's surface dedicated to a specific land use	Published
CityGML ADE		
Noise emission simulation	Employed in the simulation of environ-mental noise dispersion	Published
Ubiquitous network robot	For the navigation of robots in indoor environments	Published
Other ADEs using CityGML		
GeoBIM ADE	Defines Classes Convertible with IFC (Industry Foundation Classes). Apply For BIM (Building Information Model) Related Features.	Not published
Utility Network ADE	A CityGML ADE for Electric and Telegraphic Wires	Not published
Immovable Property Taxation ADE	A CityGML ADE for Landuse, Property Tax Related Classes.	Not published
Time Dependent Variables ADE	Being tested in i-Scope project[4]	Not published
Inclusive Routing ADE	Being tested in i-Scope project	Not published
Solar ADE	Being tested in i-Scope project	Not published

Standards for ontology in the field of geographic information have been considered since 2002 in the Technical Committee 211 (TC211) of the International Standard Organization (ISO). There is a widespread agreement amongst experts that geospatial information should or can be seamlessly combined with other cloud data for various services with ontology information. Currently, there are two documents that cover subjects of conceptual framework and implementation rules on Web Ontology Language (OWL) that have been drafted. Implementation of iKaaS data model can include aspects related to those drafts in combination with CityGML and other existing standards[5][5].

The Place Identifier (PI) architecture which was proposed by the Japanese body of TC211 also meets iKaaS data model requirements and use cases. TC211 has been working on PI and published a standard for conceptual architecture and a committee draft (CD) for a linking mechanism. PI is a type of a gazetteer which provides location linking capability together with contextual information[7][8].

B. Existing Projects

In Europe, there are several projects reporting the 3D geospatial definition and representation of a city based on CityGML. This section introduces cases in Berlin and Newcastle.

1) Berlin Economic Atlas (Germany)

a) Purpose of project : Berlin Business Location Center (BBLC) established a public-private partnership with Berlin's local government. BBLC provides an online 3D data map service[9]. They started the project in 2008 and launched the service from 2012.

b) Maintenance area: 500,000 buildings in about 890 km^2, the central part in Berlin city.

c) Data provision: Paid service (for non-business use only)

d) Providing method: Not open in public

2) EU i-Scope Solar City Project (United Kingdom)

a) Purpose of project : i-Scope project provides the services of "Personal mobility," "Solar light potential" and "Monitoring for noise and environment."[4] The 3D city data model in Newcastle city has been created for the city management by Newcastle local government[10].

b) Maintenance area: The whole area of Newcastle city *c) Data provision:* Not applicable

d) Providing method: IMGeo or CityGML format

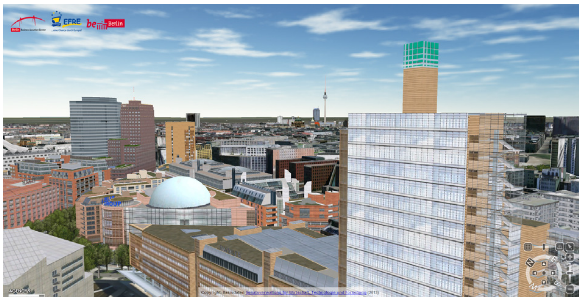

Figure 2 Screenshot of Berlin Economic Atlas web service

C. Fundamental technology for context-aware information processing

The semantic web technology has made great progress in the area of ontologies including geospatial reasoning[11], temporal reasoning[12] and event ontologies[13]. All of the above works adopt RDF as the basic data representation. Franz Inc. implemented a hybrid system which can process an arbitrary combination of geospatial, temporal and event reasoning[14].

The above mentioned are the fundamental technologies for context-aware information processing that will allow us to describe context, reason under context, and reason about context. The remaining problems are the actual data to describe the context itself.

Although there are theoretical and practical issues to discuss in geospatial and temporal reasoning, the remainder of this paper concentrates on the data model to describe the geospatial context of Tagonishi, the experimental field of the iKaaS project.

III. iKaaS Data Model

This section first shows the experimental field and lists up the community services considered in this research. Second, it proposes the iKaaS Data Model for the community services.

A. Field of Smart City Experiment

Green Community Tagonishi is a field of a smart city experiment, located approximately 7 km northeast of Sendai Station[15]. The tsunami caused by the Great East Japanese Earthquake reached up to about 2 km southeast of Tagonishi, but fortunately serious damage was not inflicted on this region. Although Tagonishi had been under construction at that time, we reconsidered significantly the initial plan to allocate the construction site, such as municipal housing for those displaced by the tsunami.

Sendai city built four municipal housing buildings in this area. This inhabited 176 households, who've lost their homes due to the tsunami or other catastrophes caused by the earthquake. Sixteen smart houses were built in the Smart Village area as individual houses. Advanced technology, architectural design and the community provide residents an eco-friendly atmosphere. (Figure 3 shows the land use zones of Green Community Tagonishi).

B. Community Services

We will assume the following community services on top of the benefits of smart city:

(1) Town Management Service
Sendai city developed apartment houses for those who lost their houses by the tsunami and the earthquake. Since this is city property, the local government has a responsibility to maintain the common facilities of the area such as roads, streetlights, parks, and etc. In Tagonishi area, Sendai Green Community Promotion Council (SGCPC) takes this business on behalf of the city and provides a town management service.

Figure 3 Land use zones of Green Community Tagonishi

(2) Energy/Water/Gas Management Service
The smart city project in Sendai was supported by the research fund from the Ministry of Internal Affairs and Communications and was developed in Tagonishi. With their funding, SGCPC provides energy/water/gas management services.

(3) Health-Care Service/Elderly Care Service
Since a considerable number of Tagonishi inhabitants are elderly, there are a certain needs for healthcare services. The structure of the service would be divided into

- service coordinator (or service broker)

- healthcare service providers

The iKaaS project proposes that SGCPC will become a service coordinator in the future.

(4) Other Services

- Information Service: in collaboration with the local government, the SGCPC will announce government issued statements in addition to community gatherings and festivities.
- Transportation Service: will provide safe navigation for the elderly to move around the city. This will also include safe commuting path suggestions for school children.

C. Overview of Data Model

iKaaS data model is a collection of necessary data classes used in the community services introduced in Section III.B. Figure **4** shows a taxonomy of the iKaaS data model. The Environmental Data Model is a model for environment description, while the Community Service Data Model is a service specific data model necessary for each service.

The Environmental Data Model consists of the Static Data Model and the Dynamic Data Model. The Major component of Static Data Model is City Data Model. Dynamic Data Model is classified into non-mobile/mobile sensor log data model where the rightmost block is a specific data class. In Dynamic Data Model, sensor object may have the following form:

Environment (non-mobile) Sensor Log Data Model
(sensor-id = <#n>,
type = non-mobile,
installed-location = <x, y, z>,
measured-value = { $<t_k, v_k>$ | k = 1, 2, 3, …. N}) (1)

Mobile Sensor Log Data Model
(sensor-id = <#n>,
type = mobile,
measured-value
= { $<x_k, y_k, z_k, t_k, v_k>$ | k = 1, 2, 3, …. N}) (2)

where x y z t in Eq (1) and Eq (2) are the values in geospatial 3D coordinates and the value in time.

D. Design of 3D Geospatial City Data Model

City Data Model is a subclass of Environmental Data Model, which is introduced for the geospatial description of a city. It describes a human living environment, together with Dynamic Data Model.

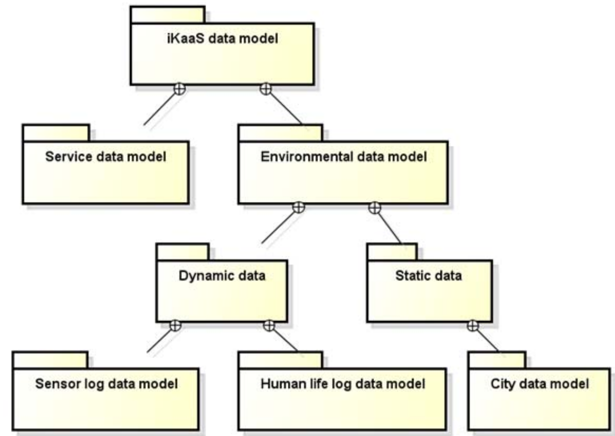

Figure 4 iKaaS Data Model overview

Figure **5** shows a refinement of City Data Model. City Data Model consists of eleven packages, and is described based on CityGML. Nine packages (Relief, Building, Tunnel, Bridge, Water body, Transportation, Vegetation, City furniture and Land use) in this data model quote the CityGML packages already standardized.

To utilize 3D geospatial city data for community services, the environmental sensors data and the underground pipes data are needed. The environmental sensors are the measuring devices such as solar panels, airflow meters, hydrometers, rain gauges, noise meters, and etc. Wearable sensors and smartphones are also defined as environmental sensors. Any sensory measurement of this type is regarded as Dynamic Data. The underground pipes are for water and gas delivery; power lines are not equal in its function.

1) Environmental sensors package

In this package the environmental sensor class is defined as a subclass of CityObject. This class has four attributes, *class, function, usage, specification,* and three associations, *lod2Geometry, lod3Geometry, lod4Geometry,* in addition to characteristics of CityObject. See Figure 6.

a) Geometry: The geometry of an object can be described as an instance of lod2Geometry, lod3Geometry or lod4Geometry association role. Lod is an abbreviation of Level Of Detail.

b) Attributes: Every environmental sensors object may have the attributes "class," "function," "usage" and "specification." The "class" attribute is used to represent the classification of environmental sensor objects such as solar panels, airflow meters, hydrometers, rain gauges, and noise meters. The "function" refers to the purpose of the object use. The "usage" attribute can be used, if the actual use of the object is different from the function. The "specification" attribute can describe conditions of environmental sensors. These attributes are described by gml::Codelist, the possible value will be specified according to the design of community services.

2) Underground pipes package

The standardizing activity related to the underground pipes package is "InfraML" which has been discussed in Open Geospatial Consortium (OGC). Since it is still under the development process of standardization, we would postpone the decision if this package should be independently defined or parallel the data model of InfraML.

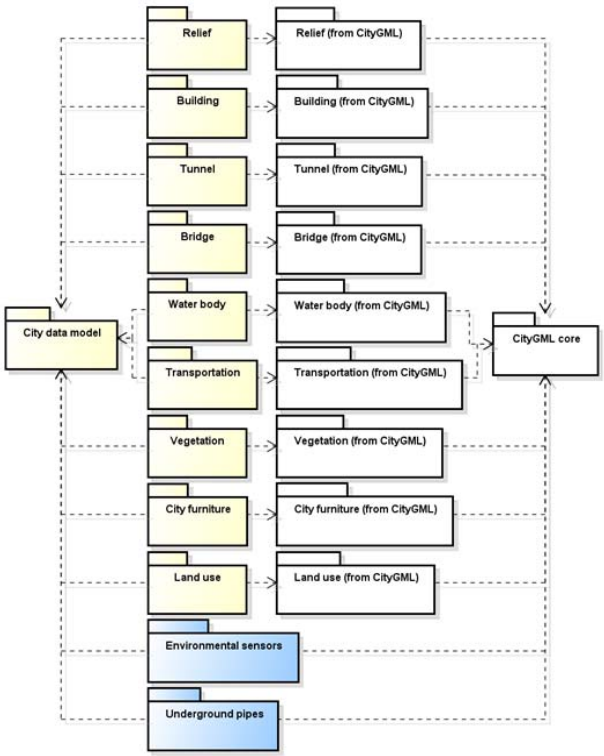

Figure 5 City Data Model overview

IV. INDICATIVE USE OF IKAAS APPLICATION

Ubiquitous assistant. In this usage shown in Figure 7, (i) awareness services and (ii) assistance services for disabled and elderly people are proposed. Regarding the first point, awareness services can include:

- "Location awareness and tracking" shall provide information on the location of the disabled and/or elderly.
- "Physical state awareness" shall monitor vital signs of the person, maintain a dynamic electronic patient record, and also monitors physical activity.

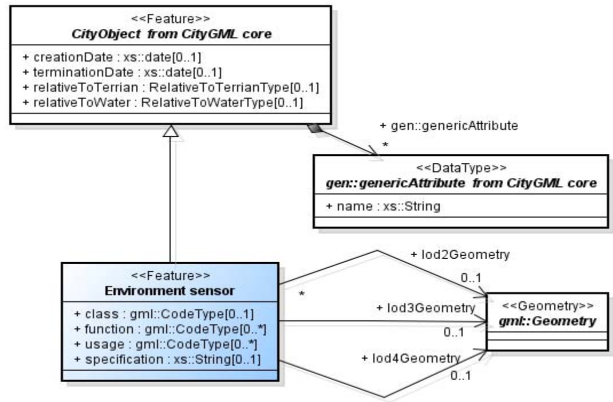

Figure 6 Contents of Environmental sensors package

Assistance Services can include:

- "Automated home environment adaptation" where home automation such as adaptation of lighting, temperature adjustment, and etc. are considered.
- "Smart mobility" shall provide instructions on how the elderly and/or disabled in need can reach a safe location etc.
- "Reminders" are there for those that need reminding of the required times to take their medication, and could potentially generate alarms in cases of taking the wrong dose/medication etc.

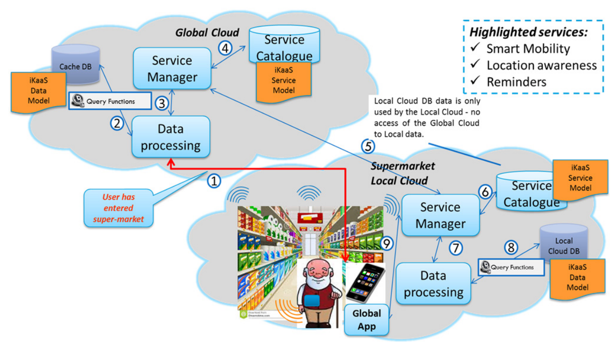

Figure 7 Ubiquitous assistant use case highlighting services of "Home automation" and "Smart mobility"

Town Management. As another use case of context aware service, iKaaS project is prototyping community services in the smart city environment deployed at the Tagonishi area in Sendai.[15] One of the services within Town asset management seeks to find:

- Amount of snowfall forecast at a specific location

- Time of current and future snow shoveling at a specific location
- Dangerous points (road surface freezing, erosion of the road, blind corner, etc.) at a town area

In the town management, an application is configured dynamically according to the user requirements, based on the "Context Overlaying" concept. The following are the core components for the context overlaying:

- Big data analysis: to estimate the context of the town in poor weather conditions. From time-series local weather data and open weather data from near district meteorological observatory, the application estimate the weather condition in the future.
- 3D Virtual Reality (VR): representation of the town on the time line. The application overlays sensor-generated data and results of the big data analysis on the 3D virtual town in the VR representation.
- Experience-based city management by using 3D VR: can provide walk-through experience from various resident viewpoints (elders, adult, children, handicap person, etc.) in bad weather condition context. The Augmented Reality (AR) based application can provide additional information.

The above mentioned town management is a good example of context-aware service. The context in this domain can be viewed as a temporal window on the sequential data collection related to town management, which includes weather conditions, air pollution, urban noise, traffic and etc. These are overlaid onto the geospatial data and are visible in the 3D VR representation. This also offers supplementary user context and privacy context data.

V. CONCLUSION

This paper introduced the context awareness personalized service studied in iKaaS project and showed the *ubiquitous assistant* and the *town management* as indicative iKaaS applications. This paper also described the iKaaS data model as a classification of the related data models and the City Data Model.

Understanding the individual user's context is the key to achieving a higher level of personalized service. However, the cost of data gathering will become the hardest obstacle to overcome to achieve context-awareness. The iKaaS project assumed that the contextual information is obtained from the town asset management and the energy management services. Town asset management is the service monitoring a variety of city objects to keep the city safe and secure. Energy management is the service monitoring energy use at each household and related devices to provide the best performance of energy use in the community. If related services can share relevant data, the burden of accumulating contextual data will be reduced. The iKaaS project is also investigating practical implementation of contextual services.

ACKNOWLEDGMENTS

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