Journal of the Korean Society of Surveying, Geodesy, Photogrammetry and Cartography
Vol. 34, No. 6, 609-618, 2016
https://doi.org/10.7848/ksgpc.2016.34.6.609

ISSN 1598-4850(Print)
ISSN 2288-260X(Online)
Original article

A Spatial-temporal POI Data Model for Implementing Location-based Services

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Abstract

Since demand for location-based services increases and the relevant service becomes more diverse, the use of POI (Point of Interest) is being required in various fields. Various roles of POI for display, search and inquiry exist, but the implementation and expression of such roles are partially limited. Therefore, the data model for implementation is suggested in this paper to enable practical implementation, expression and inquiry of POI data. The data model was developed based on 3 roles of POI including search, expression and linkage, and especially, the spatial relationship between POI objects which was not suggested in previous data models is considered and time series scheme is suggested to enable various expressions and inquiries in application services.

Keywords : Point of Interest, Data Model, Location-based Service, Implementation

1. Introduction

Since mobile devices loaded with GPS became popular, demand on location-based services increased rapidly (Lee and Yu, 2008). The location-based service is the service provided based on the location information of user (Ozdikis *et al*., 2011) and map data as the background to show the position visually and the information regarding the POI (point of interest) showing the position of main objects are necessary (Rae *et al*., 2012).

POI is information of place where people are interested or consider valuable, and it includes information of location, name and others (OGC, 2013). There is a difference between POI and gazetteer which has been actively researched previously in terms of the range of concept. The gazetteer is defined as geographical directory which contains information such as the name, spatial reference and object type of a named geographical location (Janowicz and Keßler, 2008), and it has the range of geographical location with a name. The concept of POI includes the concept of gazetteer in a wide range that topography such as land where a building object can be located, all geographic features including buildings, rivers and bridges, all facility objects including rooms and fire extinguishers and intangible objects such as historic events.

In major application services, POI is mainly used for labeling, searching an object in the in the map. Also, POI can be used to search for history of change and identify patterns of change through their time series characteristics that change over time. Despite various roles of POI for expression,

Received 2016. 11. 25, Revised 2016. 12. 20, Accepted 2016. 12. 30
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search and query exist, the implementation of such roles are partially limited currently because of absence of spatial relation expression, and time series management. Therefore, this paper suggest data model for carrying out more practical data implementation, and query through spatial relation of POI, and time series management

2. Literature Review

Currently, the international standards related to POI include ISO 19112 (ISO, 2003) which is the spatial references based on geographic identifiers that connect 'indirect' geographic references such as addresses or village names and 'direct' references that are geographic coordinates and ISO 19155 (ISO, 2012) that provides place identifiers. For the international standards regarding the POI data model, W3C POI WG (Working Group) and OGC POI SWG (Standard Working Group) carry out standard activities, but since W3C distributed the editor draft in 2012, the relevant members moved to OGC and began their activities officially on December 2015, so no international standard for POI data model exists yet. Studies for the development and utilization of POI data model are also being carried out in our country and the data model established by the Telecommunications Technology Association of Korea exists currently (TTA, 2014). For academic studies regarding POI, studies mainly utilizing POI such as studies regarding the location information-based POI recommender system (Horozov *et al*., 2006; Yuan *et al*., 2013) are being carried out actively, and studies on some data models such as modular POI data model that supported the development of various applications in a structure to be distributed for each data element such as POI core information or reservation information (Heikkinen *et al*., 2014) were carried out. In this chapter, the limitations on the range, establishment, sharing, spatial relationship and time series characteristics of current POI are reviewed based on the establishment, sharing and utilization of POI through the previous studies.

2.1 Range of definition of POI

POI is a human construct term that describes location information (W3C, 2011). Since a location can be represented with various objects, POI may include various objects. However, only an object which has a name is defined as POI and the establishment of POI data is carried out limitedly with objects that have attribute data including object, ID and name. However, objects with no specific name such as cctv and objects that do not actually exist such as historical events also exist besides objects that have a name (Jung, 2016) and the function and role of POI such as search and query in various application services such as 'search indoor fire extinguisher' are required for such objects. Therefore, the previous range of POI should be expanded to include objects such as facilities and intangible objects.

2.2 Establishment and sharing of POI

POI data is mainly established by portal companies and government agencies according to its various utilizations. In case of Korea, approximately 12 companies establish POI data according to their purposes and government agencies also establish separately or purchasing POI data from the companies (NGII, 2014). At this time, approximately 70% of POI data established separately is overlapped and there is no unified system in government for the items, so mutual sharing between the government agencies is not carried out properly, causing financial loss.

Such problem seems to be caused by absence of clear standard about POI data and low level of data sharing accordingly. TTA POI data model standard exists in Korea but data details for sharing and linkage are insufficient. Also there is no international standard data model, the Ordnance Survey establishes POI based on SIC (Standard Industrial Classification) (OS, 2014), and PSMA establishes such data based on ISO19131 (PSMA, 2016).

Clear standards for data details such as identifiers for linkage or the unified classification system for sharing are necessary for efficient data establishment and sharing, and this also enables securing of mutual sharing in various web services, so the data model that includes clear standards is necessary.

2.3 Spatial relationship of POI

Currently, data at different spatial depths have been established as POI data (NGII, 2015). However, the

relationship of inclusion according to spatial range exists between POI objects and for an example, a point of interest existing in the indoor space of complex facility and a point of interest which expresses the complex facility itself have different spatial depth to each other. The number and type of POI displayed on the screen according to the scale of the map should be displayed differently according to the spatial depth of POI for data display. The hierarchical structurization according to such spatial attributes should be established for data utilization but previous data models use only structured hierarchical relationship between POI for non-spatial attributes. TTA POI data model which is one of the Korea POI standard also has a limitation that the parent-child structure of POI class indicating the point of interest is made in the association relationship so that it only forms the set without spatial structurization (TTA, 2014). Also, POI Core draft which is the POI data model distributed by W3C POI WG cannot express spatial relationship, just present the class which indicates the set of POI (W3C, 2012).

POI data models presented currently have no consideration on the spatial depth. A data model that can summarize the spatial depth of POI for classifying POI expressed according to the scale of map and executing spatial query is necessary.

2.4 Time series characteristics of POI

POI has time series characteristics that location changes over time and the significance of temporal change information exists as record that expresses changes in national industries and the phases of the times. If POI data is managed time sequentially based on such characteristics, it can be utilized in change history search service and pattern analysis on the location and name in the past. However, change history such as addition, deletion and update of domestic POI data is in form of overwriting attribute fields without a table for saving the change history, so actual change history is not managed (NGII, 2015). Also, data specification for managing POI change history does not exist in the data models such as TTA POI data model and W3C POI data model that exist currently, so there is no measure for solving such issue.

According to this section, the spatial relationship between POIs is not expressed so the implementation and expression of query such as the spatial relationship between objects or spatial navigation are limited. Also, there is no unified for sharing or linkage of POI data, so studies on the standards such as identifiers of data are necessary. Lastly, the management of time series characteristics of POI is not carried out currently so that the application services through the time series management of data are also limited. Therefore, ① the spatial hierarchy is expressed, ② the standard for sharing data is prepared, ③ and the data model for implementation that enables time series management is suggested in this paper for carrying out more practical data implementation, expression and query.

3. Spatial-temporal POI Data Model

In the POI data model, the describing POIs for detailed description of POI data and the implementing POIs in Apps designed in details in order to present the direction to establish actual POI data and utilize and implement established POI data in the application service exist. Among these models, it is intended to suggest the POI data model for implementation in this paper and it is based on the W3C POI data model (abstract model) suggested by W3C POI WG in 2012. The suggested data model was designed to supplement the limitations of current POI data described previously and the data model was developed based on three functions of POI including search, expression and linkage and sharing. The object and logical relationship of the model presented in this paper were expressed with UML (Unified Modeling Language) diagram.

3.1 Considerations

In consideration of characteristics, there are 3 functions and characteristics of POI displayed to users in web map and web service that need to be observed for sharing data and utilizing application services as shown in Fig. 1. Searching of an object such as location and geographic feature, display of data on the service and linkage and sharing of established POI data can be considered as the main applicational functions of POI as well as the requirements for the data model, so it was intended to develop the data model suggested in this paper based on such three functions.

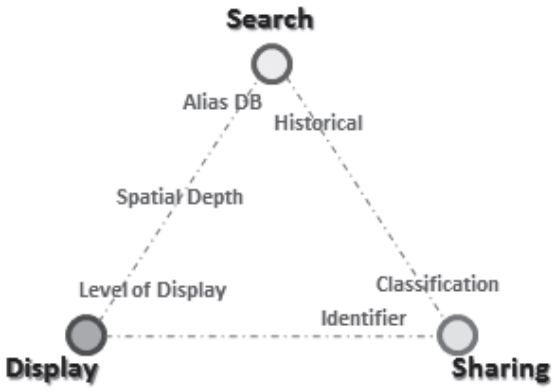


Fig. 1. Developmental direction of POI data model

In terms of search, the POI data model should be the model for semantic search and time series search. The semantic search where user search is easy should be possible through the DB establishment for the accurate name of POI object and similar alias information, and the location of POI may change over time, its utilization in the application service requesting history search through the management of location information change history should be possible.

Numerous POIs established on the application services cannot be expressed at the same time. Therefore, the method to express POI on the service screen efficiently is the method to express POI limitedly according to the expression level, and spatial range can be considered as the expression standard of POI according to the expression level. The relationship of inclusion actually exists between POIs according to spatial range and hierarchy should be established in order to enable the explicit expression of such spatial relationship. Through this, the expression level according to the spatial depth can be defined and routing between POI becomes possible due to the spatial hierarchy.

Due to its quantitative characteristics, it is efficient to utilize previously established data by various agencies and organizations for POI data. Previously established POI data has attribute information such as location and name information basically so that mutual sharing is possible and it can be medium that plays a role of link to data held by other agencies and organizations. For the linkage with original DB, an identifier which contains the code information of linked agencies is necessary and unified classification system of POI is necessary for mutual sharing of POI data, so the basic definition of data schema such as a code that specified such classification system is necessary.

Therefore, the data model for implementation intended to present in this paper is the model for semantic search and time series search, model for expression by considering the spatial depth and POI data model for linkage and sharing. In this chapter, the Generic Data Model in consideration of basic elements of POI data model and spatial relationship between POIs and the POI expansion model that supports time series information management based on such model are suggested.

3.2 Levels of POI

For establishing POI data, it is necessary to define the range of POI in 3 levels and the attribute of object according to the level is defined differently. POI which should be established as the first level is the objects in real world that have a name including buildings, geographic features that have object, ID and name as the attributes. POI corresponding to the second level is objects with no specific name such as CCTV including streetlights, benches and road facilities and POI in this level have object and ID as the attributes. Intangible cultural assets or historic events correspond to the third level and objects that do not exist actually are included and have only name as the attribute in this level.

In this paper, the Generic POI Data Model based on the First level of POI is presented and it is expanded to the Data Model that expresses Second level & Third Level of POI later.

3.3 Generic POI data model

The Generic POI Data Model suggested in this paper was designed by considering the alias information for search, framework and spatial relationship for data sharing in addition to the basic elements of the previous POI Data Model discussed in the precedent study.

3.3.1 Alias

For smooth POI search, it is necessary to establish DB for various alias information of POI objects. In case of user search for a specific object, it is necessary to enable searching

with an accurate name as well as a similar search word for user's convenience, and this is more effective when the name of an object is long, complicated or a compound word. For example, if the official name is 'IBK Industrial Bank of Korea ** branch', it can have alias information such as 'IBK Industrial Bank of Korea' or 'I-B-K Industrial Bank of Korea ** branch' for the convenience of user search. Therefore, the Generic POI Data Model for such semantic search has POI_Alias Class, the class that expresses alias information. POI Class has 1:N aggregation relationship with POI_Alias Class, so POI object should have a number of alias information, POI_Alias Class has alias, date of creation and deletion as the attributes (Fig. 2).

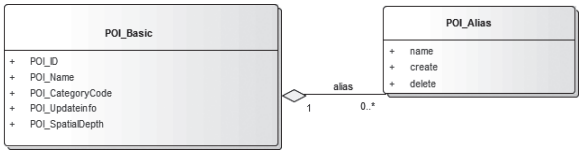


Fig. 2. Aggregation for alias

3.3.2 Spatial Hierarchical relationships

Hierarchy exists in POI object according to its spatial depth and a data model which can establish it to improve the data utilization is necessary. POI data model developed in this paper has Self-aggregation for Spatial Hierarchy relationship as the spatial hierarchy structure in order to explain the relationship between POI in the district unit and other POI in the district or building unit existing inside of such POI (Fig. 3). Spatial depth-based Spatial Hierarchy of POI is expressed as the Self-aggregation of POI_Basic Class, and each POI Instance has 0~1 parent or 0~N child as the attribute information (Fig. 3(a)). For example, Space-based hierarchical structure relationship that Dongdaemun-gu as shown in Fig. 3(b) corresponds to parent POI and Univ. of Seoul is child POI of Dongdaemun-gu, Cheonnong Hall is child POI of Univ. of Seoul is established.

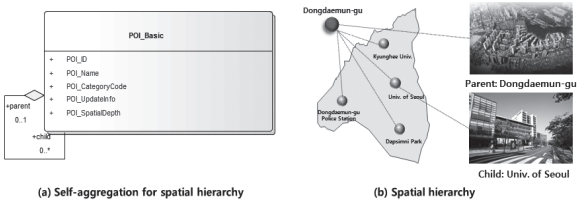


Fig. 3. Self-aggregation for spatial hierarchy

3.3.3 Spatial depths

POI expression on the application service enables expression for each scale through the definition of spatial depth-based expression level. The spatial depth and hierarchy of POI object can be expressed as the Spatial Depth of POI_Basic Class, and the Spatial Depth of each POI shown in Fig. 3(b) can be expressed as Cheonnong Hall:1, Univ. of Seoul:2, Dongdaemun-gu:3 respectively. The expression level of POI object according to such Spatial Depth is defined through the user-define so that each POI object is expressed in 1~N levels, and this is established through the aggregation relationship between POI_Basic Class which has Spatial Depth shown in Fig. 4 as the attribute and POI_DisplayInfo class which has the expression level as the attribute. Also, it is also possible to express at the level desired by the user separately from spatial depth by defining the POI expression level independently according to the user's purpose and importance of POI.

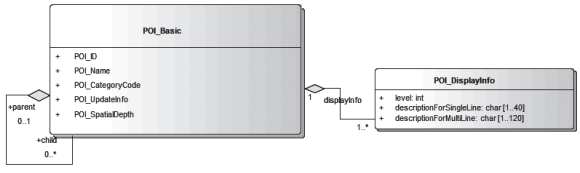
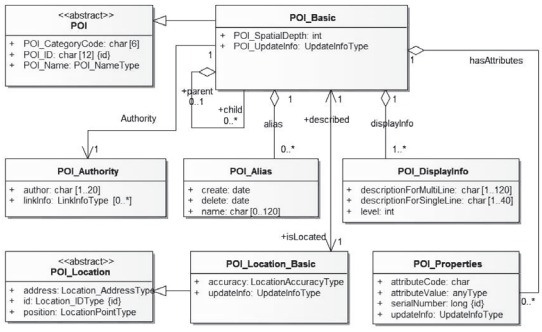


Fig. 4. Aggregation for display

3.3.4 Generic POI data model

Due to such characteristics, Generic POI Data Model consisted of 6 classes including POI_Basic Class, POI_Location_Basic Class, POI_Properties Class, POI_DisplayInfo Class, POI_Alias Class and POI_Authority Class and each class and the relationship were described in the UML diagram (Fig. 5(a)).

POI_Basic Class is the class which expresses POI object and it expresses spatial hierarchical relationships through the Self-aggregation of POI_Basic Class and has attribute information of POI as the logical relationship with each class. The location information of object has 1:1 relationship with POI_Location_Basic Class, and the attribute information of object has 1:N set relationship with POI_Properties Class,



(a) UML diagram of generic POI data model

```
POI_Basic{
        POI_NameType POI_Name;
        char POI_ID;
        char POI_CategoryCode;
        int POI_SpatialDepth;
        UpdateInfoType POI_UpdateInfo;
        POI.POI_Basic child;
        POI.POI_Location_Basic isLocated;
        }

POI_Location_Basic{
        LocationAccuracyType accuracy;
        UpdateInfoType updateInfo;
        Location_AddressType address;
        Location_IDType id;
        LocationPointType position;
        POI.POI_Basic described;
              }
```

(b) POI_Basic and POI_Location_Basic class DB scheme

Fig. 5. Generic POI data model

and copyright information has 1:1 relationship with POI_Authority Class. Also, it has N number of alias information as the set relationship with POI_Alias Class and one or more expression information as the set relationship with POI_DisplayInfo Class as mentioned earlier.

POI_Basic Class which indicates POI object and POI_Location_Basic Class which indicates location information that is the most important element of POI inherit POI abstract class and POI_Location abstract class respectively, having attribute each and becoming data (Fig. 5(b)). At first, POI_Basic Class which inherits POI abstract class has ID, Name, CategoryCode, UpdateInfo, Spatial Depth and child (parent) as its attributes. ID for object identification is composed of a 12-digit character string combined with the code information of linked agency and the serial number of the object and Name which shows the official name of the object is expressed as data type (POI_NameType) that includes Korean alphabet, English alphabet and Roman alphabet. The classification system is shown through the attribute information of CategoryCode for POI classification and it has UpdateInfo which indicates information regarding the creation and update of POI object and Spatial Depth for expressing the spatial hierarchy as the attributes.

POI_Location_Basic Class inherits POI_Location abstract class and has ID, position, address, accuracy and updateInfo as the attributes. ID has location information ID data type (Location_IDType) such as PNU and the position which indicates location is expressed in data type (LocationPOIntType) that can be expressed in 2D and 3D coordinates and address which indicates address is expressed in data type (Location_AddressType) that includes parcel number-based address, road name based address, Administrative Dong code and legal Dong code. The accuracy attribute which indicates the accuracy of location is expressed as a value among survey result, field survey, drawing survey and grant of address position for the accuracy of location of object and information regarding the creation and update of location information is expressed as updateInfo attribute.

POI_Properties Class has attributes including serialNumber, attributeCode, attributeValue and UpdateInfo. serialNumber means the serial number of attribute item and attributeCode is the pre-defined code of attribute type. attributeValue has attribute values in various types (anyType) and indicates information regarding the creation and update of attribute information through UpdateInfo.

POI_Alias Class which plays a role of alias has attributes including Name, Create and Delete that indicate the alias name, date of alias creation and date of alias deletion. POI_DisplayInfo Class which plays a role of screen output of POI object has level, descriptionForSingleLine and descriptionForMultiLine as the attributes. Level means information on the degree of LOD (Level of Depth) outputted on the screen and descriptionForSingleLine which is the name of POI single line description or descriptionForMultiLine which is the name of POI multi-line description is expressed according to the level. POI_Authority Class which plays a role of author information has attribute author which indicate the name of POI creator and attribute linkInfo which indicates the information of linked agency. linkInfo is expressed as the data type (LinkInfoType) which describes reference No., agency code, agency name, update code and additional explanation.

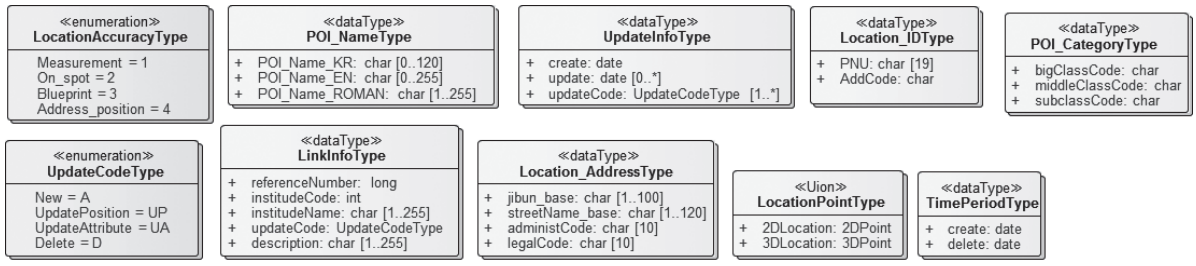


Fig. 6. Data type and code list of generic POI data model

The attributes of each class in the Generic POI Data Model have the code list according to each data type as specified in Fig. 6 and the attributes are defined accordingly.

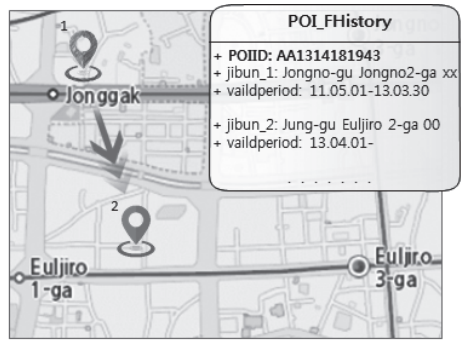
3.4 Spatial-temporal POI data model

The location of an object such as a building may change over time and an object which is located on the relevant area may change according over time for the topography where the building is located. In other words, the location of POI which covers the range such as geographic features and specific locations may change over time and POI expansion model which manages the location information change history is suggested in order to provide the service using such feature.

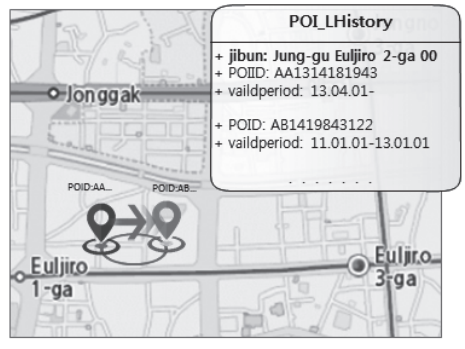
3.4.1 Two ways to describe spatial-temporal POIs

Two measures for time series management of POI exist. One measure is the management of history based on POI object and the other measure is the management of history based on location information (Fig. 7). POI object-based history management means the management of location information that changes for POI (Fig. 7(a)). This method manages history such as the case that POI object called "Woori Bank Jongro Branch" was located on "xx, Jong-ro 2-ga, Jongno-gu, Seoul" from May 1, 2011 to March 30, 2013, but its location has changed to "00. Eulji-ro 2-ga, Jung-gu, Seoul" from April 1, 2013 to the present.

History management based on location information means the management of POI that changes for the fixed location (Fig. 7(b)), and for example, it manages history such as "Kookmin Bank Jong-ro Branch" existed on the location of "00, Eulji-ro 2-ga, Jung-gu, Seoul" from January 1, 2011 to January 1, 2013 but "Woori Bank Jong-ro Branch" has existed on such location from April 1, 2013 to the present. Like this, if the history of POI is managed through these two measures, both location change and object change of POI over time change can be managed and the history search service in various forms can be supported.



(a) Feature-based spatial-temporal POI



(b) Location-based spatial-temporal POI

Fig. 7. Two ways to describe spatial-temporal POIs

3.4.2 Spatial-temporal POI data model

The POI expansion model for POI time series management was developed by adding classes for feature-based time series management and location-based time series management

measures based on the Generic POI Data Model presented earlier (Fig. 8). The specification of data type and code list is same with the Generic POI Data Model.

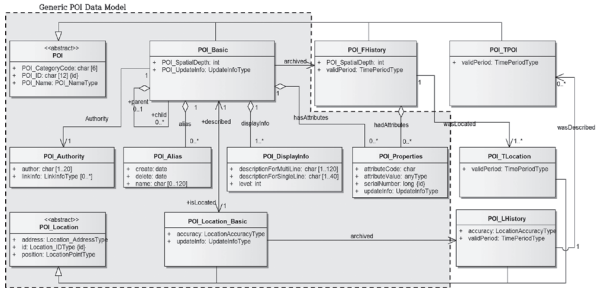


Fig. 8. UML diagram of spatial-temporal POI data model

The classes added to Generic POI Data Model for time series management include POI_FHistory Class, POI_TLocation Class, POI_LHistory Class and POI_TPOI Class, and POI_FHistory Class and POI_TLocation Class are classes for feature-based time series management and POI_LHistory Class and POI_TPOI Class are the classes for location-based time series management. POI_FHistory Class and POI_TPOI Class inherit POI Class and include the attributes of POI Class, and POI_Location_Basic Class, POI_LHistory Class and POI_TLocation Class inherit POI_Location Class and include the attributes of POI_Location Class. The feature-based time series management in the Spatial-temporal POI Data Model is carried out based on POI_Basic, POI_FHistory and POI_TLocation Class, and the location-based series management is carried out based on POI_Location_Basic, POI_LHistory and POI_TPOI Class.

POI_FHistory Class for the feature-based time series management is the class to save object-based time series information which is related to POI_Basic Class, playing a role of archived, and POI_TLocation Class is the class that expresses information on the location of POI. POI_FHistory Class has the attributes of POI_Properties and POI_SpatialDepth same as POI and it also has vaildPeriod that saves period information from the creation of the relevant POI to its extinction as the attribute. validPeriod which POI_TLocation Class has is the period information that POI is created and becomes extinct on the relevant location. 1 POI object can have 1 or more location information, so POI_FHistory Class has 1:N relationship with POI_TLocation Class.

POI_LHistory Class for location-based time series management is the class to save location-based time series information which is related to POI_Location_Basic Class, playing a role of archived, and POI_TPOI Class is the class to save information of various POIs that existed in the relevant location. POI_LHistory Class has accuracy which indicates the accuracy of location and vaildPeriod which saves period information from the creation of the relevant POI to its extinction and inherited attributes. POI_TPOI Class has inherited attributes and validPeriod that saves the period information that POI is created and becomes extinct on the relevant location additionally. Since 0 or more past POI objects can exist at one position, POI_LHistory class has 1:N relationship with POI_TPOI class.

4. Experimental Implementation of the Spatial-temporal POI Data Model

The characteristics of POI data model suggested in this paper include that the spatial relationship between POI objects is hierarchically structured and designed to enable the time series management of POI. In this chapter, POI object was established as an example and the history search result of POI object was implemented with object-based time series management as an example among the routing through spatial hierarchy, POI routing and time series management measures.

In this experiment, a total of 10 POI object nodes as shown in Fig. 9(a) were created and the actual spatial relationship between the created POI objects is expressed as shown in Fig. 9(b). For the spatial relationship search result of object nodes, '21st Century Building', 'Univ. of Seoul', 'Dongdaemun-gu'

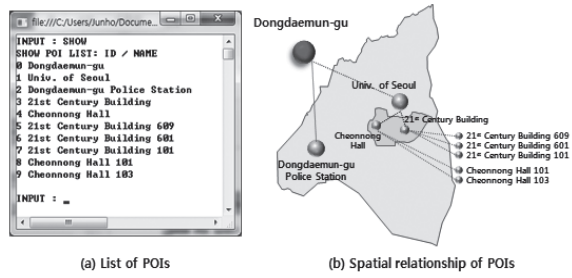
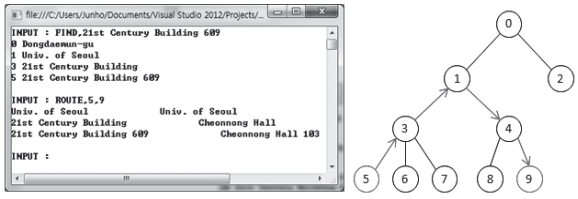


Fig. 9. Spatial relationship of POIs and POI list

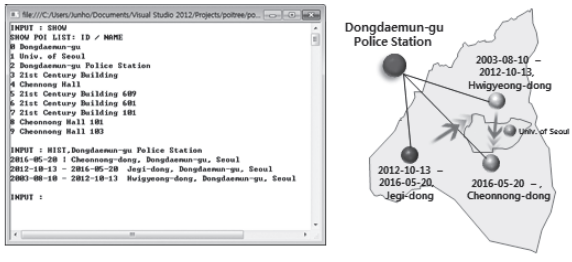
were searched sequentially as parent node (parent) as a result of searching '21st Century Building 609' POI object node in Fig. 10(a). Also, as a result of routing '21st Century Building 609 (ID:5)' and 'Cheonnong Hall (ID:9)', 'Univ. of Seoul' which was the common parent node of two object nodes, confirming the spatial connectivity between two object nodes. When the routing result of two object nodes is considered from the viewpoint of node-link relationship, spatial search is carried out as shown in Fig. 10(b) and the result is outputted.



(a) Result of querying POI nodes and spatial relationship (b) Routing POI nodes

Fig. 10. Experimental implementation of spatial hierarchical relationships of POI

Also, the time series management measure of the suggested data model enables various history search services since POI object has history information as attribute information (validPeriod, address) just as the search result in Fig. 11(a) Searched 'Dongdaemun-gu Police Station' POI object node has address information of the previous location and the relevant period information (Fig. 11(b)) as the attribute information.



(a) Result of querying feature-based spatial-temporal POI (b) History of POI loaction

Fig. 11. Experimental implementation of feature-based spatial-temporal POI

As results of experiments in this chapter, spatial relationship search, like routing between POIs, is possible through spatial hierarchy, and the history information POI has can be searched. Likewise, routing between POIs and the expression of object for each level are possible through spatial hierarchy, and the application service to utilize history search will be possible through time series management.

5. Future Studies and Conclusion

POI is useful information on a specific location, can be utilized for various purposes. However, its utilization is limited currently. Therefore, the expansion model for implementation was developed in this paper by expanding and modifying the previous POI data model in order to implement more useful expression and query of POI.

The data models were developed based on 3 roles of POI including search, expression and linkage and the developed data models include Generic POI Data Model and temporal POI Data Model where classes for time series management are added. The establishment of POI alias information DB and spatial hierarchy, definition of expression levels and the assignment of identifiers and classification system were enabled in the Generic POI Data Model. Spatial-temporal POI Data Model was composed of feature-based time series management to manage location information that changed for POI and the location-based time series management to manage POI that changed for the fixed location to support history search service in various forms. Through the data model developed in this paper, routing between POIs and the expression of object for each level are possible through spatial hierarchy, and the application service to utilize history search is possible through time series management.

The data model presented in this paper has the following limitations. First, the Categorycode attribute for expressing the classification system of POI was presented but the classification standard by stage of POI object classification was not presented. Lastly, the expansion of the data model where Second level & Third Level of POI can be handled is necessary in a further study.

Acknowledgments

This study is prepared based on the research report of '2015 National Internet Map and National Point Of Interest Information Expansion and Establishment' from the National

Geographic Information Institute under the Ministry of Land, Infrastructure and Transport.

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