Middleware for Translating Urban GIS Information for Building a Design Society Via General BIM Tools

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Abstract

This study proposes a middleware based on a geographical information system (GIS) and related information as part of an initiative toward open data platforms, which has been undertaken by countries such as the USA, UK, Australia, and India through websites with names like 'data.gov'. Other governments, including Australia, with a national map of 2D map information have not yet provided GIS-based open data and open application programming interfaces (APIs). On the other hand, the Korean government has actively opened up GIS-based information called VWorld and open APIs. However, the building industry has not yet exploited this information, and it seems to lack accessibility. Therefore, authors aim to support fast and expanding open data and propose a middleware that uses VWorld as a target platform for searching, processing, and generating GIS-based open data toward realizing building information modelling (BIM) exchangeable information. A Web 2.0 based middleware should be different from a Web 1.0 counterpart so that open data from suppliers are guided and delivered to data consumers in customized data formats. Authors expect that this study will serve as a general guiding approach for harvesting GIS-based open data as soon as other governments provide open data in the near future. Therefore, it should lead to dramatic improvements in acquiring environmental information relevant to building design, thus enabling better decision-making during design.

Keywords: CAD/BIM/GIS integration; Open Data; National Geospatial Database; BIM/GIS middleware; BEIM

1. Introduction

This study focuses on the CAD/BIM/GIS integration issue. Time and effort is required for collecting site-related information beyond building design from distributed sources. Google Earth, a type of Virtual Globe, has emerged as an important source from which designers could obtain geospatial information relevant to analysing building sites. Architects and designers are familiar with tools such as Google Earth, which provides access to geographical information system (GIS) information, which allows them to extend their scope of data from building design to broader regions. Furthermore, building information modelling (BIM) tools have provided the building industry with access to data beyond the building domain, enabling GIS-related as well as building lifecycle considerations.

In light of these broad changes in the architecture, engineering, and construction (AEC) industry, authors provide an overview of the current trends to obtain a generalized perspective of these changes. Web 2.0 and Government (Gov) 2.0 suggest new mind-sets that differ from the Web 1.0 and Gov 1.0 era. Countries such as the USA, UK, Australia, and India[16,) 17), 18), and 19)] are moving toward providing open data through sites with names like 'data.gov'. The Korean government has set a similar innovation goal for e-government[15)]. The essence of these reforms lies in the open data concept, where the new role of government is to serve as an information platform that provides open data with continuously generated public data; publicly owned contents in the fields of culture, knowledge, and art, which are not necessarily a focus of governance; and broadening the public license to use them. Countries including Korea and the USA are rapidly and broadly opening up public data and maximizing the accessibility, participation, and transparency of public assets providing open data, open interface platforms, and open standards with proper formats for the betterment of social infrastructure so that public data is easily available to people.

The Korean Ministry of Land, Infrastructure and Transportation (MLIT), as one of the efforts toward e-government, has opened up public data and a Virtual-Globe-like geospatial information platform by providing a tool called VWorld, which is a subordinate

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platform of the National Spatial Information Distribution system. This tool enables access to credible, rich, and wide-ranging geospatial contents for domestic building contents that exceed counterparts such as nonlocal services, including Google Earth.

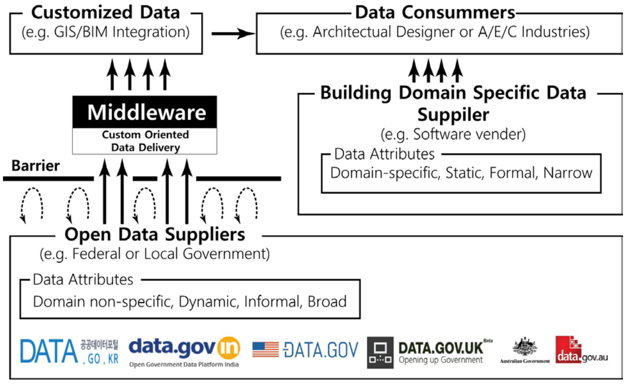


Fig.1. Data Supplier and Consumer Diagram for Building Environment Information Modelling

In this study, authors propose a middleware that is applicable to the move toward Web 2.0 and Gov 2.0 for the AEC industry, as shown in Figs.1. and 2. This is because the building industry has not yet exploited the newly available information, and authors view this as a golden opportunity that could revolutionize the building industry. Authors suggest a middleware that is distinctively different from Web 1.0 counterparts, for example, search agents in information portals. Open data is not easily accessible to the public, especially the building design industry. Data suppliers, even those having favourable intentions, do not make public data available to appropriate and would-be data consumers. This proposed middleware takes so-called 'open data' and delivers it to data consumers in a customized form. It performs operations including search, processing, and generation and takes dynamic 'open data' and converts and delivers it to a consumer in the form of ready-to-use customized data for the building industry. By using GIS information, it can deliver smart, situated, and domain knowledge to the right people in the right format for the building industry.

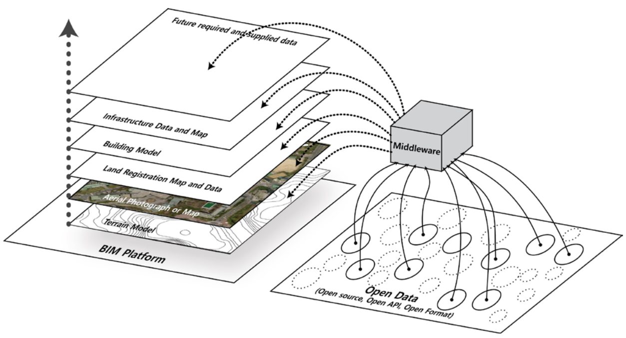


Fig.2. Role and Distinctive Characteristics of Proposed Middleware

Authors based the middleware on VWorld, taking into account its disadvantages and limitations as well as Korean domestic and local issues. However, the efforts should be considered general because this methods and solutions are based on open and standard methods. This study strongly focuses on GIS-information-based methods, adoption of open standards such as XML, and open application programming interfaces (APIs) so as to not limit the scope to only domestic VWorld geospatial data. One can choose between VWorld and Google Earth, and it is expected that foreign countries will follow a similar open data policy with GIS information in the near future.

2. Related Works

Authors focus on system development research to support building design using GIS data and examine studies related to CAD/BIM/GIS integration to enhance the efficiency of managing building information through BIM data construction using GIS data. The Korean MLIT made VWorld available to the public and started a web service offering domestic geospatial information; this motivated authors' present study.

SketchUp has long been used to provide geospatial information using satellite photos from Google Earth, in which the 3D forms of buildings worldwide are stored and presented. Many Google Earth plugins have also been developed for existing BIM authoring tools[10]. Some domestic studies have investigated building design using GIS data in Google Earth. Both domestic and overseas studies have been limited to handling only satellite photos and latitude/longitude information.

In contrast, VWorld provides a wide range of geospatial information including not only satellite photos and latitude/longitude information but also more information that could benefit building experts if it were available in the appropriate format of existing BIM tools. Furthermore, BIM models that contain GIS coordinates, such as VWorld, would gain easy access to building related information in their own database.

2.1 CAD/BIM/GIS Integration

The Open Geospatial Consortium (OGC) is a non-profit organization for the geospatial information standards. It specifies the need for CAD/BIM/GIS integration to realize enhanced interoperability of design, construction, and maintenance information covering the building and infrastructure lifecycles[11]. The National Institute of Building Science (NIBS), the national research institute that suggests and manages BIM standards in the USA, recently established a National BIM Standard that suggests that the scope of building information should be extended from the minimum building scale to world-scale information; such larger-scale environmental information will naturally require GIS data. NIBS suggest the hierarchical structure of information scales/scopes and leads to the subject of CAD/BIM/GIS integration[6].

CAD/BIM/GIS integration is difficult because it involves the processing of large amounts of information; this is because it is considered essential to handle large-sized 3D-model-based building data. Some of the most efficient approaches to this issue are concepts such as the use of level of detail (LOD) as well as the hierarchical separation of 3D model information based upon the hierarchical structure specified by the National BIM Standard. CAD/BIM/GIS integration is indispensable for information systems covering cities, states, and the entire Earth. However, current information systems are mostly concerned with building up urban infrastructure information systems but excluding information about buildings, which mainly constitute a city-scale information system. Existing and current Google Earth based 3D city examples[1), 5)] provide only the building exteriors without any building-related information integrated in them; this is a crucial problem and is mainly caused by large-scale 3D data processing.

Efforts and solutions are found from system development for airport geospatial information management. The Denver and Los Angeles international airports, with the adoption of BIM, applied GIS to manage buildings and infrastructure scattered across airport sites using not a 3D model base but a 2D drawing base because of large-scale 3D data processing (Fig.3.). These airports adopted Revit for BIM software and ESRI ArcGIS for GIS software; however, these tools are not considered capable of processing 3D data in real time. In contrast, the IIA ISMS covers more than 180 buildings over a large site, and real-time processing of large-scale 3D land, building, and spatial information was critically required. Therefore, instead of using existing commercial building design tools, they developed exclusive software, developed a file format for handling lightweight 3D data, and constructed hierarchically structured 3D data based upon this custom format. IIA also focused on enhancing the strong immersive experience of end users who perform the actual management tasks by adopting a 3D game engine based real-time rendered visualization 3D viewer instead of using existing building design 3D viewers (Fig.4.)[4)].

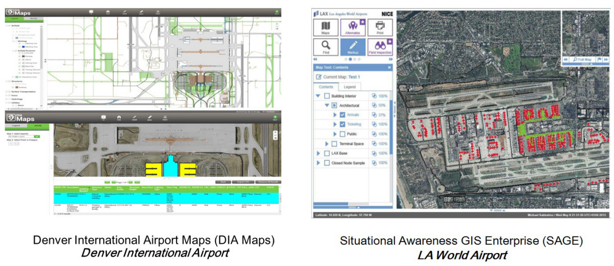


Fig.3. Examples of Geospatial Information Management at Denver and Los Angeles International Airports

2.2 Use of GIS with Virtual Globe

Virtual Globe[20)] is known as the main gateway to GIS information that maximizes the contact frequency

Fig.4. Incheon International Airport Integrated Spatial Management System

for non-expert users because it is convenient to use and provides a strong immersive environment for users. Therefore, Virtual Globe, as a search platform for 3D model based GIS information, could be treated as a virtual reality Earth. Among many examples of Virtual Globe applications, there is a BIM-related example such as a web-based 3D facility and device management system for scientific stations in Antarctica. This example demonstrates various GIS and BIM data as well as functionalities including inquiries for various properties and 3D space search through a platform server constructed using WWJ (World Wide Java), an open source platform that serves as the engine of World Wind, which is NASA's Virtual Globe[9)].

A research case suggests a method to build up building information using Virtual Globe, which serves as a search platform for building information[3)]. It also demonstrates a way to produce building mass from Google Earth information and building heights. It illustrates a way to automatically construct data for thousands of buildings, including GIS coordinates, building outlines, address data, floor data, and building names. The research also shows a way to construct building data in Google Earth using a BIM model. It is noted that the building mass model easily works in Google Earth; however, the converted BIM model does not work smoothly because of the large size of the 3D model. A partial solution to this issue[2)] suggests the adoption of an appropriate level of model for distinguishing in Google Earth and a separate link to an exterior BIM viewer for a more detailed level of the building model.

Research examples such as the one mentioned above are rather focused on the platform aspect of the information search than on the Virtual Globe information and its direct application. CADtoEarth[8)] of AMC Bridge for Autodesk products is a good example of applying Virtual Globe geospatial information to BIM software. This software sends 3D topological data from Google Earth to Revit and inversely sends Revit building models to Google Earth. The main shortcoming of this case is that satellite photos are provided as the geospatial information for the building project; however, other building-site-related geospatial information is beyond the scope of this software. The other way of converting information for GIS/BIM integration is to manually process the topology and satellite photo information to transform into data formats for BIM authoring tools such as Revit and ArchiCAD.

3. GIS Data Application System for Building Design Support

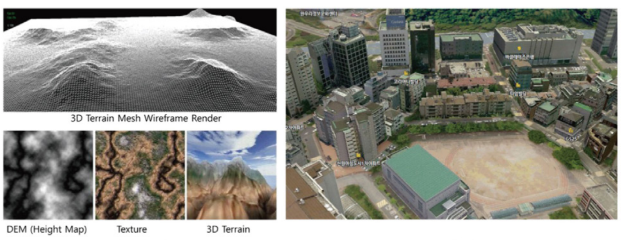
3.1 VWorld Data and API Analysis

VWorld uses its own exclusive data format. It also uses the KML data format used in Google Earth but not the Collada format in Google Earth. In particular, VWorld uses its own format called Real3D for a 3D building model; however, the system is yet to serve 3D building modelling data until now because the format analysis is not complete, and therefore, 3D building form support is not yet provided in the system and is not considered in this paper. Table 1. shows the types of data for terrain maps in VWorld.

Table 1. Data Types for Contour Maps in VWorld

Classification	Extension	Description
DEM	*.bil	Height map data in Tile Region
Point	*.poi	Point of Interest (POI) symbol data in Tile Region
Billboard	*.poi	Billboard symbol data in Tile Region
Real3D Index	*.dat	Index data of Real3D (Model) symbol in Tile Region
Real3D Model	*.xdo	Form data of Real3D (Model)
Direct Show Surface	*.dds	Satellite Image data in tile Region

The Digital Elevation Model (DEM) is the 3D coordinate of terrain for the construction of a GIS with a set of heights for regular intervals. There are similar data formats such as Digital Terrain Model (DTM), Digital Terrain Data (DTD), and Digital Terrain Elevation Data (DTED). It is called the Real3D model, which is a 3D model specific to VWorld, and it is constructed using both aerial photography and an aerial laser survey using LIDAR. This data format is capable of high definition texture and network data streaming. Fig.5. shows examples of DEM and Real3D. Satellite photography processing adopts an image format called direct draw surface (DDS) that can perform video image compression to save video memory resources. However, there are some problems with this image format. The first is the low image resolution. The next problem is that it is not a generic image format and therefore image format conversion is required.



DEM Real3d

Fig.5. DEM for Terrain and Real3D for 3D Buildings in VWorld

VWorld provides various geospatial information covering 132 items. This information is publically obtained from the Korean government including the Korean MLIT. The building design related information obtained from the MLIT is shown in Table 2.

Table 2. Geospatial Information Served by MLIT through VWorld

Classification	Services
Development activity permit map	1. Development activity permit limit region 2. Infrastructure charges zone 3. Development activity permit plot 4. Land transaction permit zone
National traffic information map	1. Traffic link 2. Traffic node
Etc.	1. Land registration map 2. Walking priority zone 3. National name of place
Urban planning facilities map	1. Road 2. Traffic facility 3. Space facility 4. Logistic facility 5. Public culture & sports facility 6. Security Facility 7. Sanitation facility 8. Environmental foundation facility 9. Infrastructure 10. Etc.
Industry site map	1. Complex boundary 2. Complex purpose boundary 3. Complex facility land 4. Complex invited business
Use districts map	1. National plan district, 2. Park district, 3. Limited Development District
Use zone map	1. Scenery 2. Aesthetic 3. Height limit 4. Fire prevention 5. Disaster prevention 6. Preservation 7. Facilities protection 8. Settlements 9. Development promotion 10. Limit specified use
Use region map	1. Urban 2. Supervised 3. Agricultural 4. Natural environment preservation
District unit plan map	1. District unit plan

VWorld provides eight types of open APIs[14] for the developers (summarized in Table 3.) and two types of data lists. It provides terrain forms and map images through a 2D map, 3D map, and background map APIs. WMS and WFS APIs provide data in the WMS and WFX layer lists in the form of a feature map. The remaining APIs are for supporting the search operations through which authors could search for address data, road-name-based address data, or a new building's address. It also provides geocoding functionality that converts into GIS coordinates using address and names in the map.

Table 3. Types and Contents of Open APIs Obtained from VWorld

API Classification	Description
2D map API	Serving 2D map
3D map API	Serving 3D map
Base map API	Serving Base map, Image map, Hybrid map
WMS WFS API	Serving variety of spatial information
WMS, WFX Layer List	Serving variety of feature maps as 2D/3D map
Data List	Serving data of 132 items
Data API – new building address	Building location and number of road name address system
Data API – complex boundary	Variety of spatial information for national plan
Search API	Searching a place with address and name of place and serving Geocoding and reverse Geocoding
Static MAP API	Serving hash-up function to overlay user-defined information on Base, Image, and Hybrid map

Data request using the road-name-based address API is performed as follows using a URL.

"http://apis.vworld.kr/2ddata/spbd/data?apiKey=validationKey[&domain=validatedDomain]&requestVariable"

The conversion results from the above inquiry are the new type of address, building outline information in 2D polygons, and building-related data including building name, English name, and building floors. The site boundary API from the Industry Site map provides geospatial information such as site category, site name, and site boundary shapes. A data request is performed using a URL as shown below, and the result is the name of the classification site boundary, name of site, and land boundary polygon data.

"http://apis.vworld.kr/2ddata/damdan/data?apiKey=validationKey[&domain=validatedDomain]&requestVariable"

Form-related information in the land registration map is provided in the form of coordinates without specific file formats in VWorld. This explains the fact that a request for land registration map related information is processed and received in the form of XML in which both polygon information and property information exist. The received XML file contents for the request of 'N Seoul Tower National Theatre parking lot' are shown below.

http://apis.vworld.kr/2ddata/cadastral/data?apiKey=46E68FFB-2557-3DB3-AA5E-DA1479542A6D&domain=http://corp.kovi.com&geometry=point(14137619.6359031%204516255.06244297)&output=xml&srsName=EPSG:900913&pageIndex=1&pageUnit=100

Fig.6. shows the received XML file including land registration data and land plot polygon data.

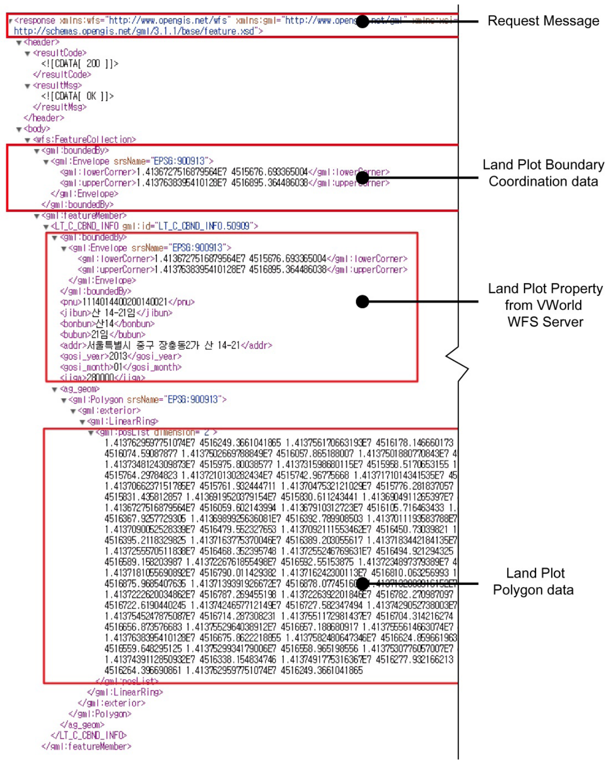


Fig.6. Request Result in XML for 'N Seoul Tower National Theatre Parking Lot'

3.2 System Design and Development

The system design objective is to develop a middleware that can process VWorld supporting geospatial information into formats that are usable in the early phase of building design and provide formats that work smoothly in BIM authoring tools. Authors restrict the target BIM authoring tool only to Revit version 2014.

Fig.7. shows the system architecture, where important components are referred to as A, B, C, and D. The middleware part is the system core. The VWorld system is the GIS DB. Revit is the BIM software. VWorld Desktop is a type of Virtual Globe. A360 is a Revit–BIM viewer. These parts are connected around the middleware. The middleware consists of the following parts. The search part is used for requesting data from VWorld. The convert part is used for converting the received data so that the middleware can process it. The Revit convert part is used for converting data to generate Revit objects so that Revit models could be handled in VWorld Desktop. Request keywords cover various forms. However, it is more appropriate to use the lot number address for better results because of the land registration map. The search results are suggested in lists and images (2D map and satellite photo) so that users can identify them. The data conversion part takes various received data (DEM, Real3D, XML, Coordinates) into geometries and properties to be used internally in the system. The

geometry includes 3D terrains, 3D buildings, satellite photos, map images, and land registration maps. Property includes information related to categories of land, region and district, building, and others. The received data are converted into Revit objects such as terrain object, mass objects for buildings, and property line object for land registration map. Property information is saved as custom user-defined parameters to appropriate objects.

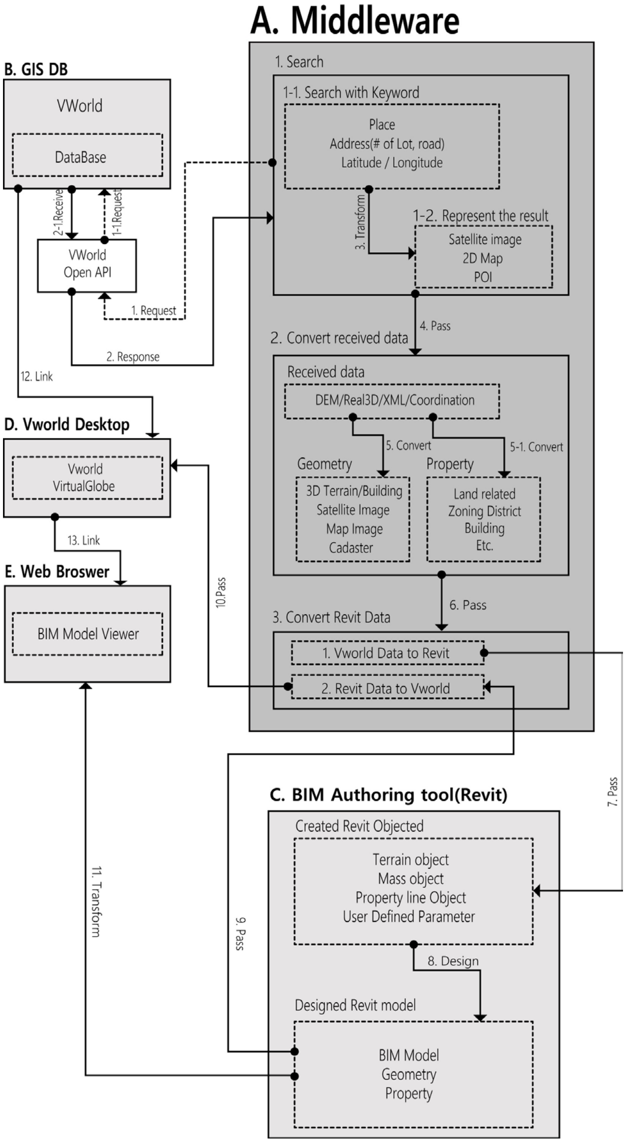


Fig.7. System Architecture

The VWorld Middleware, when implemented as shown in Fig.8., involves creating two Revit objects. First, the contents, implemented classes, functions, and scripts in the search part are as follows with numbers indicating the processing order (Table 4.):

Table 4. Function List for Searching to Request Data to VWorld

Function, Class, or Script	Description
RibbonUI::Callback_TextBox_AddressSearch_EnterPressed()	
	A search request using area information keywords from the TextBox input.
MainLogic::SearchAddress()	
	Dialog creation for the search results and setting of the GeoPoint value for the selected terrain, which is used in terrain generation later.
UI_Search_List::BTN_ADDRESS_SEARCH_Click()	
	After keyword search using the wrapper function in VWorld, search results are outputted in list control.
VWorld_OpenAPI_Wrapper::AddressSearch()	
	Request for Poi/Jibun/Juso or XML formats using the search URL. Using http://map.vworld.kr/search.do/result/poi to acquire the numbers of searched plot names and processed to display in a page list using those numbers and page operations
VWorld_OpenAPI_Wrapper::AddressSearchResultParseFromXML()	
	Processing queried search results and parsing them into structure lists.
UI_Search_List::LISTVIEW_ADDRESS_RESULT_ItemSelectionChanged()	
	An item selected from the search result lists is displayed in the map display window using item coordinates and map mash-ups
VWorld_OpenAPI_Wrapper::ConvertAddress2Cordinate()	
	Converting a searched item's primary coordinates from EPSG:4326 into EPSG:900913
http://apis.vworld.kr/jibun2coord.do?q=[Address]&apiKey=[Key]&domain= [Domain]&output=[returnType]&epsg=[Coordinates]&callback=[func]WebBrowser::InvokeScript()	
	Renewal of map browser using converted coordinates and mash-up script
Mashup_Script::SetPositionCoord()	
	Settings of x and y locations and creating marker of VWorld apiMap.

Second, these search results are converted into Revit objects using Revit object creation functions. The Revit object creation, created classes, functions, and scripts are as follows (Table 5.):

3.3 System Development Results

The VWorld Middleware as a Revit plugin that implements functions for storing related information of terrain object creation, mappings of satellite photographs onto terrain, land registration map creation, and user-defined parameters of a Revit property line object. The analysis of the Real3D file format has yet to be completed, and therefore, a building model format converting function is not equipped in the middleware. However, the Revit building model is extracted into the surface model and transmitted into VWorld in the KMZ (compression format of Keyhole Mark-up Language (KML)) format for the mash up in VWorld. The detailed building model is far too complex to be directly displayed as a mash up in VWorld, and therefore, these models are provided via a web browser link for viewing.

Table 5. Function List for Transforming the Data which was Received from VWorld to Revit and Generating Revit Objects

Function, Class, or Script	Description
MainLogic::MakeTerrain()	Request for DEM information for the selected area that leads to a request to Revit for terrain object creation
MainLogic::GetNodeData()	Request for DataNodeInfo3D list in the area using GeoPoint of the selected plot number list
VWorld_OpenAPI_Wrapper.DataSearchRequest()	Request for DEM information for areas and levels and acquisition of information list
VWorld_OpenAPI_Wrapper::DataNodeListParseFromXML()	After parsing the acquired search result, the defined results are processed into structure lists
VWorld_OpenAPI_Wrapper.LayerNodeDataRequest()	Acquisition of terrain data and image data and storage processing by DEM index and levels
DEM_Manager::AddDEMData()	Parsing the stored terrain information and assignment to DEM storage structure
Map_Manager::AddTileMap()	Assignment of stored image data as a TileMapImage structure list
MainLogic::MakeTerrain()	Setting of terrain surface information through DEM by GetNodeData(), and setting to Autodesk.Revit.DB.XYZ class array for the DEM information by a 65 x 65 loop and position height calculation
Revit SDK::TopographySurface::Create()	Delivery of adjusted Autodesk.Revit.DB.XYZ and creation of terrain object in Revit
World_OpenAPI_Wrapper.Ref2D_Data_Request()	Request for and processing of property information

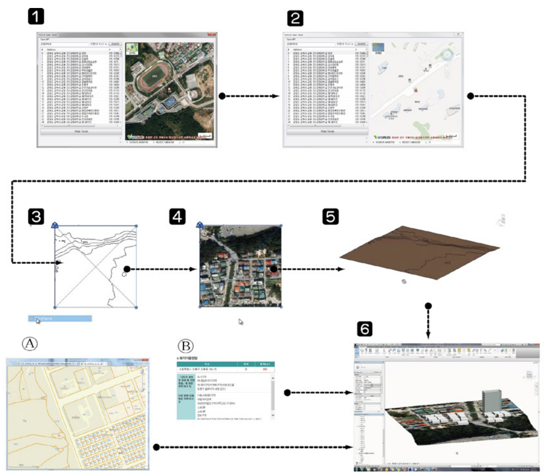


Fig.8. Illustration of System Operation

Fig.8. illustrates the system operation results. Panels 1 and 2 indicate the start-up display and search window of the VWorld middleware, respectively. The difference between the two lies in the type of maps confirming the search locations; panel 1 uses satellite photography and panel 2 uses a base map. Panel 3 shows the site map display result of the converted Revit topography object for the selected area. Panel 4 shows the satellite photography mapping result for the Revit topography object. Picture A shows the resulting search in the form of a land registration map and picture B, the property information of the searched land, which includes the address, area, development act related restrictions, zoning district information, and appraised land value. Finally, panel 6 shows the integration result, which illustrates the result of the initial assessment of the buildable volume based upon the acquired information.

4. Discussion and Vision

Recently, a strong need has emerged for methods for the heterogeneous integration of CAD/BIM/GIS. However, few cases thus far have demonstrated integration in real building design projects, especially building projects requiring large-scale administrative support at the national scale. On the other hand, the MLIT case of VWorld is especially meaningful because it is initiated by the Korean government and is aimed at serving as an interdisciplinary tool in the commercial building and construction industries for large-scale design environments. Korea could currently provide a perfect test bed for CAD/BIM/GIS integration studies because of its excellent information technology and communication infrastructure. This study is one of the early efforts toward realizing better and more efficient interdisciplinary building information integration that could possibly integrate the seemingly heterogeneous and separate scopes of buildings, cities, and nations.

BIM provides the building industry with various opportunities for an integrated platform to cover two open-end categories, form and properties. It could lead to collaboration among existing building work areas such as architectural design, building structure, and building MEP. However, BIM is currently a closed system owing to its strict requirements of information completeness. If BIM usage were to be feasible only at the level of a building or group of buildings, further interdisciplinary communication would be hindered. Thus, the scope of BIM needs to be extended from a building, to a town, city, and nation. Both the breadth and depth of BIM need to be extended. Authors are trying to clarify authors' vision by constructing a reformed glossary for Building Environment Information Modelling (BEIM) instead of simply BIM. BEIM will focus more on not individual disciplines but interdisciplinary applications of the form and properties of an artificial environment. Authors anticipate near-future situations such as architectural designers and urban designers seeking new parameter sets, and therefore, even the MLIT is aiming to provide better sets of artificial environment parameters.

This paper focuses on developing a middleware system that would benefit existing BIM users such as building designers, who suffer from the lack of relevant project information in government-initiated public geospatial information databases. Authors expected that the main group of users for most BIM authoring tools will be building designers, and therefore, authors mainly examined information that could be acquired from VWorld in the form of familiar formats and project-related knowledge such as site terrain objects; satellite photos; and various types of geospatial information including a 3D building model with exterior texture, 2D polygons of building outlines, and various properties of artificial environments such as buildings, sites, and roads. BIM authoring tools are mainly used by building design experts who tend to focus on physical entities and design information for building construction. It is rational for us to start with BIM/GIS middleware functionality to initially cope with the site design issues faced in building projects. Therefore, authors primarily tried to verify the usefulness of the system from the viewpoint of building design experts. The system is therefore demonstrated as a middleware for the two sibling disciplines of building and urban design so that building design results based upon standard GIS coordinates for one or more buildings in a large-scale project area are mutually beneficial to both parties by providing appropriate data and information for BIM as well as GIS. This middleware could enrich both GIS and BIM information systems and would save much time and effort.

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