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Original scientific paper

Development of Augmented Reality Underground Facility Management System using Map Application Programming Interface and JavaScript Object Notation Communication

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Abstract: With the rapid development of IT in the modern society, various kinds of information such as smart information age are provided in real time regardless of time and place. Especially, various IT devices and mobile devices using the ubiquitous concept are being widely used in real life and helping to make life convenient. Currently, various ubiquitous services and management schemes are being tried in the government business field. This paper was performed to propose an augmented reality-based system construction and service environment plan for the management of underground facilities such as gas, electricity, communication, water supply, sewerage, heating, and oil pipelines. To do this, the author used Map API and JSON communication technique. JSON can be used in JavaScript programs without parsing or serialization. Also, JSON is a text-based way to represent JavaScript object literals, arrays, and scalar data. As a result, it can be transmitted in a format that can be interpreted in fields that utilize various types of data. Using this JSON, an augmented reality-based underground facility management system was implemented. In other words, it is a system that can find and modify the location of underground objects without drawing drawings in the field through communication between the tablet and the server. Especially, it suggested a method to provide and manage the location information of GIS (NGIS, KLIS) system and the facilities embedded in the underground, and attribute information by replacing the location mark used in existing underground facilities. Through the augmented reality based underground facility management system, it is expected to be effective in terms of practicality, economics, real - time network, information provision and management, and prevention of major accidents. In addition, it will be an effective method for updating and maintaining information related to underground facilities. Finally, by applying the augmented reality-based underground facility management system, it is possible to precisely measure the underground facility survey and condition for an existing buried pipe or a new public pipeline. Through augmented reality technology, it is possible to check the facilities of obstacles as if they were right in front of you. In addition, facility management, history management, and on-site management are possible at once, and it is characterized by convergence with other IT and quick decision-making by integrating the management system.

Keywords: augmented reality; GPS; JSON communication; map API; underground facility management

1 INTRODUCTION

Today, the world is rapidly becoming urbanized, and population densities due to rapid urbanization are causing typical urban problems such as traffic congestion and deteriorating ecological environment. As a representative example, difficulties in urban management such as waste disposal, public hygiene, and security problems are increasing. Especially, despite the efforts of the government in the management of underground facilities, there are many damages and inconveniences because the number and types of underground facilities to be managed are large and it is impossible to visually confirm them due to underground burial [1, 2].

Underground facilities refer to certain underground facilities such as water pipes, drain pipes, electric power facilities, telecommunications facilities, gas supply facilities, public areas, underpasses, and subways. The managers of these underground facilities should periodically conduct and report safety checks in accordance with the safety management regulations for underground facilities and surrounding grounds for the area in charge.

Underground facilities are buried in the ground. Therefore, there are difficulties in management due to the inconsistency of design and construction due to rapid industrialization and urbanization, and the complexity of underground facilities [3]. In addition, systematic management of underground facilities is very important in that the management becomes poor and unexpected accidents occur, resulting in loss of life or property. In particular, in the past, underground facilities as well as above-ground facilities were often damaged due to inaccurate location information and negligence in management during underground excavation work. Therefore, it is important to systematically manage underground facilities.

Therefore, in constructing an integrated map of the underground space of underground facilities, it is necessary to construct two-dimensional underground facility pipelines in three dimensions. To this end, it is necessary to solve the problem of concavities and convexities caused by the problem of connection of pipelines divided by section and data errors of the source data of underground facilities. In the end, system design and implementation that can express and manage underground facilities as a three-dimensional model should be performed [4, 5]. To solve this, a convenient and safe underground facilities management system through the combination of advanced information technology and physical environment should be developed and applied. In particular, underground facilities are a key part of the city's core infrastructure, and the need for systematic and efficient management is increasing. Research on related technologies such as GIS, sensor, network, and digital contents is being actively carried out, so that it is necessary to acquire accurate information on facility-related information and to maintain and manage it in a steady state by grasping the location and condition of underground facilities.

As a typical example of underground facilities, systems for managing water pipe, drain pipe, etc. need to be developed and implemented with various GIS software. To this end, a basic design document should be prepared by specifying the basic design elements required for general-purpose system development. However, in most underground facility platform, the management system is unclear due to the lack of integrated management of the underground facility DB, inaccurate location information, and non-standardization of work. In other words, information on each underground facility is required not only by the management entity that manages the facility, but also by other organizations. It is necessary to integrate and manage related information. In addition, even if several underground facilities are integrated and managed, location information is inevitably different because each uses a different scale. It is necessary to manage accurate location information by integrating information on underground facilities input at different scales into one basic map.

To solve this, recently, many countries are developing systems for managing underground facilities such as smart underground facilities management technique, intelligent underground facilities management network development technology, intelligent water and drain pipes asset management system development and dissemination [6].

Therefore, in this paper, the author has developed a systematic management system for underground facilities by applying augmented reality technology. To do this, the author used Map API and JSON communication technique. Augmented reality-based underground facilities management system is a system that can locate and modify the location without drawing in the field by communication between tablet and server in relation to underground objects. Finally, 2D and 3D map engine interworking and linking technology using augmented reality was developed and applied to the system. Through this, data verification was performed in real time on underground facilities through augmented reality, and interworking with the spatial data GIS engine was performed based on the underground facilities management system. And, it provided smooth interworking service of 2D and 3D maps.

2 RELATED WORK
2.1 Augmented Reality

Augmented reality is a hybrid virtual reality technology that combines reality and virtual environment using technology that shows real world three-dimensional virtual objects overlaid. Augmented reality is a technology that superimposes virtual objects on the real world that the user sees. In other words, it is a field of Virtual Reality, which is a computer graphics technique that combines virtual objects or information into a real environment and makes it look like objects in the original environment [7]. The augmented reality is to increase the effect of reality by combining the virtual object on the environment of the real world, unlike the virtual reality which assumes the complete virtual world.

Since the establishment of augmented reality, a lot of interest and research on augmented reality is in progress. In the early stage of marker-based augmented reality, various techniques were studied for realtime tracking. In particular, inertial tracking, magnetic tracking, acoustic tracking, GPS tracking, optical tracking, etc. have been developed. Afterwards, as sensor-based tracking develops, tracking technology based on current computer vision technology is being applied to the development of smart augmented reality contents. Recently, vision-based tracking technology has been developed, but the characteristic dragging or shaking phenomenon has been raised as a problem. In order to solve this problem, augmented reality tracking technology that takes advantage of each advantage by convergence of vision technology and sensor technology is being developed and utilized. In order to implement such augmented reality technology, a direction sensor, an inclination sensor, wide connectivity, a GPS sensor, a camera, etc. are required. Currently, many smart devices are equipped with core devices and technologies for implementing augmented reality, so they can be implemented more easily [8, 9].

3D stereoscopic technology includes augmented reality and virtual reality. Both technologies have a similar format called 3D implementation, but they are clearly distinguished by whether the subject is illusion or reality. Augmented reality is a popular technology that is widely used by the general public. However, virtual reality is generally used only in special environments such as movies and video [8, 9].

There are several necessary things to realize Augmented Reality. GPS devices that send and receive geographic / location information, and gravity (tilt + electronic compass) sensors (or gyroscope sensors). In addition, a location information system in a network connection state in which detailed information according to sensor information is stored is needed. There is a need for an augmented reality application that receives detailed information and displays it on a realistic background, and finally an IT device such as a smart phone or a tablet PC is required for outputting it to a display [10].

The augmented reality is characterized by the combination of virtual information spaces that are reproduced by computers in the real space, that virtual information is displayed in coordination with the position and content in the actual space, and that information can be interacted it is processed in real time. In other words, computer graphics technology has been developed to add automobiles and robots that were not in production at the time of editing in the editing process. That is, it is a feature of augmented reality technology that a virtual image can be synthesized and displayed in real time in accordance with the environment of the user, and these virtual objects or information can be manipulated and interacted with each other [11].

In order to realize the augmented reality, it is necessary to recognize the objects that are the background of the augmented reality correctly. In the case of camera tracking, which is generally used, the camera recognizes the mark or surrounding objects and provides the location information to the central database. Another system for acquiring location information is GPS technology, which is used in the augmented reality realization principle that holds information that must be provided by absolute user location. And electronic compass gravity sensors. These technologies are used collectively to realize augmented reality [12].

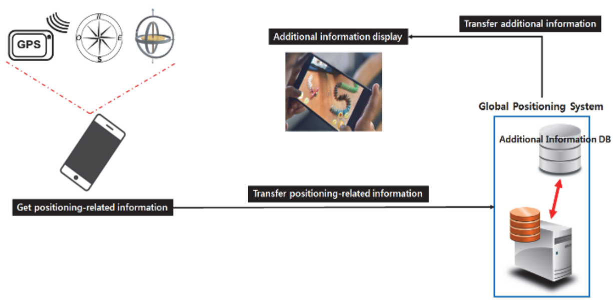

Figure 1 Augmented reality realization principle

Fig. 1 shows the principle of augmented reality. In this paper, the author has developed a system that provides the augmented reality - based output screen to the manager to efficiently manage the underground facilities reflecting the characteristics of the augmented reality.

2.2 JSON Communication

The abbreviation for JavaScript Object Notation (JSON) is an expression used to create an object in JavaScript. This expression is easy for people to understand, machine is easy to understand, and the data capacity is small. For this reason, JSON has been replaced by XML in recent years and is used for storing settings and transmitting data. JSON is a lightweight data-interchange format, which means an expression used to create an object in javascript. JSON expressions are easy to understand for both humans and machines, and because of their small size, JSON has recently replaced XML and used them for data transfer [13, 14]. It does not depend on any particular language, and it provides a library that can handle data in JSON format in most programming languages.

JSON is based on two structures.

- Collection type in pair of name/value type: realized in object, record, struct, dictionary, hash table, keyed list, or associative array in various languages.
- An ordered list of values: realized in most languages as an array, vector, list, or sequence.

These are universal DATA structures. In fact, all modern programming languages support them in any way. It is natural that a compatible DATA format using programming languages is based on these structures. The object, array, value, string, and number formats used in JSON are as follows. First, object is an unordered SET of name / value pairs. Objects are represented by starting with a left brace ({) and ending with a right brace (}). Each name is followed by a colon (:), and comma (,) separates name / value pairs. Second, array is an ordered collection of values. An array is represented by starting with a left bracket ([) and ending with a right bracket (]). Separate array values with comma (,). Fig. 2 shows the object and array formats [15-17].

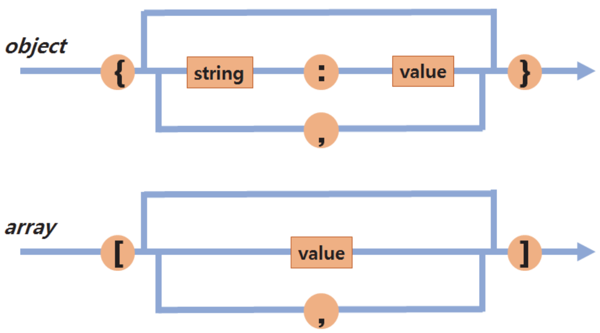

Figure 2 Format of object and array

Third, value can be string, number, true, false, null, object, or array in double quotation marks. Fourth, string is a combination of zero or more Unicode characters enclosed in double quotes, enclosed in double quotes, and backslash escaped. A single character is also represented as a character string. A string is very much like a C or Java string. Fig. 3 shows the string format.

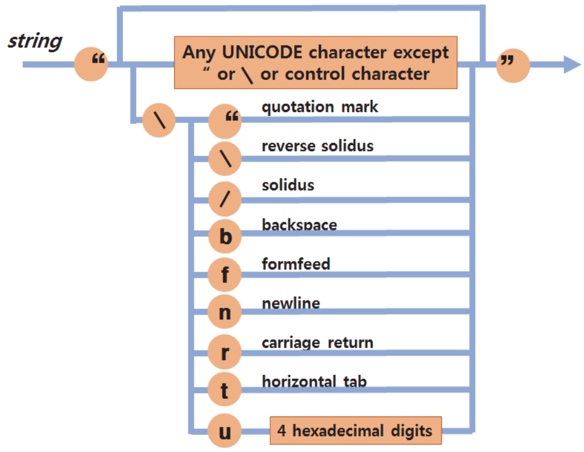

Figure 3 Format of string

Finally, number is very much like C and Java number except that it does not use octal and hexadecimal formats. Fig. 4 shows the number format.

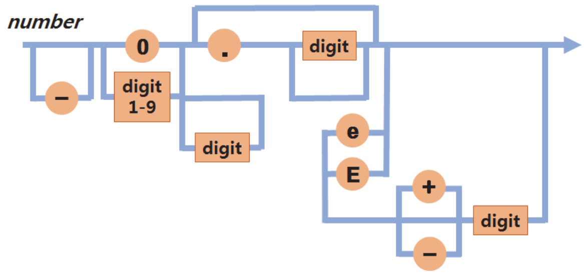

Figure 4 Format of number

Up until this point, the author has been focusing on JSON primarily from a front-end perspective. However, as a data interchange format, JSON plays an important role on the back end of our applications as well [18]. Therefore, in order to further empower ourselves in the ways of JSON, the author will explore how to set up our very own web server, utilizing an open source technology known as Node.js [19, 20]. Node.js, commonly referred to as Node, is a runtime environment created that allows us to devise a web server using nothing other than JavaScript.

JSON is lightweight text-data interchange format - smaller than XML, and faster and easier to parse JSON is language independent - it uses java script syntax for describing data objects, but independent of any language. An API is a specification intended to be used as an interface by software components to communicate with each other [21, 22]. An API may include specifications for routines, data structures, object classes and variables can take many forms. International Standard such as POSIX or vendor documentation such as the Microsoft Windows API, or the libraries of a programming language can be language-dependent - only available by using the syntax and elements of a particular language, which makes the API more convenient to use language-independent - written so that it can be called from several programming languages. The practice of publishing APIs has allowed web communities to create an open architecture for sharing content and data between communities and applications. Content that is created in one place can be dynamically posted and updated in multiple locations on the web. User information can be shared from web communities to outside applications, delivering new functionality to the web community [23].

3 SYSTEM MODELING

In this paper, the author designs an augmented reality facility management system that enables facility managers to check underground facility data by using map API underground burial facilities such as waterworks and sewer pipes buried underground.

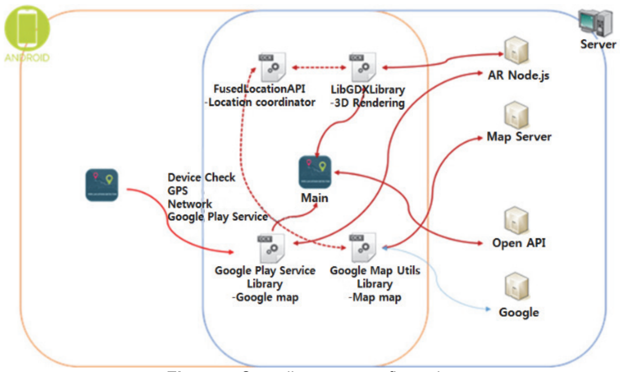

Figure 5 Overall system configuration

Fig. 5 shows the overall system configuration diagram. First, when the underground facilities management program is executed, the checking on the device is performed. Device check checks whether GPS is enabled, network is enabled, and whether Google Play Service is installed. When the device check is completed, a server connection is attempted and various data processing is performed.

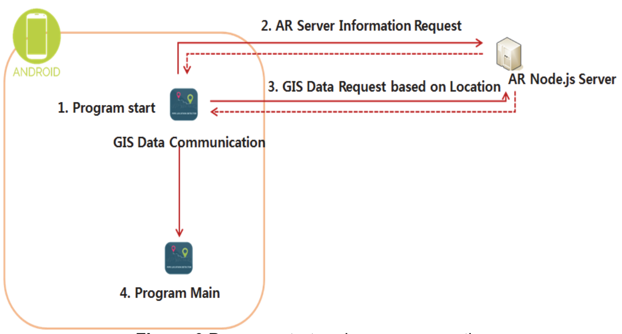

Figure 6 Program start and server connection

Fig. 6 shows the design of the initial program start and server connections. When the initial program is started, the AR server information is requested. The AR server information request consists of AR server activation confirmation and current location information transmission. AR Node.js Request location is based on GIS data through server and executes main screen. In this process, detailed procedures such as device GPS and network check, Node.js server connection, GIS data processing, JSON communication, program intro end and main execution are performed.

The design for starting AR mode and starting Google Map mode is shown in Fig. 7. The system modeling for the start of AR mode starts with facility check and rendering. Then, real time GPS information transmission is performed, and data update is performed through request position calculation and server transmission. It performs JSON communication through AR Node.js server and 3D rendering through LibGDX Library. System modeling for starting Google Map mode begins with the Google Play Service Library. Thereafter, the user location transmission, the request location calculation and the server transmission are performed, and the data update proceeds [24]. JSON communication is performed through Map web server, and facility coordinates and property values are generated through GeoJSON Data. It also creates a marker and a line through the map render.

The manual position correction is performed in the same manner in the AR mode and the MAP mode. Manual position correction requests GIS data for the specified position from Google Map to Map Web server through Google Map Utility Library.

The Map Web server transmits facility coordinates and attribute values through JSON communication, and generates markers and lines through Map Render.

In updating AR and Map data, select the position radius, select the range item, and send it to AR Node.js server and Map Web server, respectively. The data is updated through the transmitted data and transmitted to the LibGDX Library and Map Render through JSON communication. Finally, 3D rendering is performed through the LibGDX Library, and markers and lines are created through Map Render.

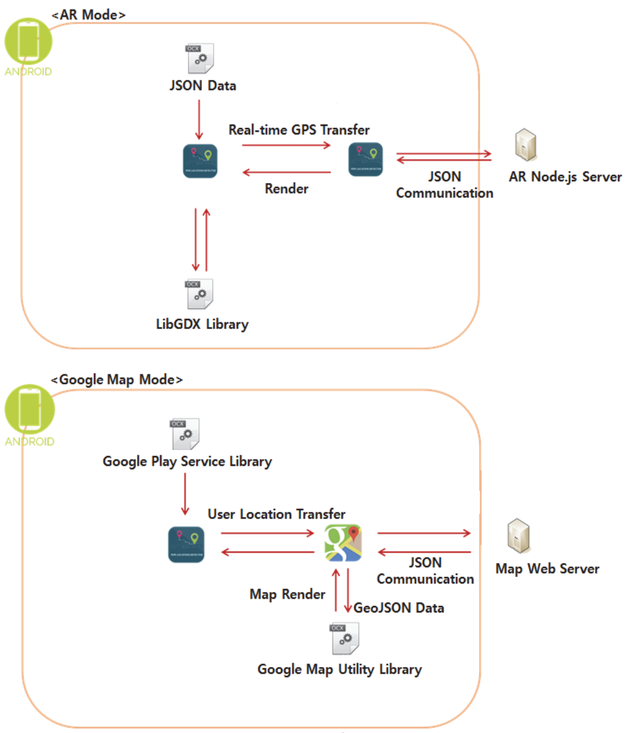

Figure 7 AR mode and Google map mode

4 SYSTEM DEVELOPMENT

The engine of the augmented reality part used in this paper is a desktop or mobile platform game engine below LibGDX. Insufficient scalability and data output limitations of location-based and GIS programs due to the limitations of the LibGDX engine were confirmed. Therefore, in order to reduce the limited scalability and data mapping error, it is necessary to minimize the error caused by augmented reality execution, the dynamic error caused by the time delay, and the error caused by the sensor measurement.

This paper was conducted to developed lines with a user-desired radius rendered using GIS coordinate information for underground facilities. Then, it was changed to move the viewpoint using the device's GPS and sensor. In the end, the data was confirmed within a sophisticated error range through engine development through marker method and actual measurement mapping.

Tab. 1 and Tab. 2 show the hardware and software information applied to develop augmented reality underground facility management system based on MAP API and JSON communication.

Table 1 H/W information

File system	Total capacity	Capacity used	Usable capacity
/dev/mapper/VolGroup-lv_root	50G	24G	24G
tmpfs	9.8G	72K	9.8G
/dev/sda1	477M	96M	356M
/dev/mapper/VolGroup-lv_home	858G	25G	790G

Table 2 S/W information

Software	Version
MariaDB	10.0.15
Apache	2.4.10
PHP	5.5.20
Python	2.7
tomcat	8.0.15
Java	1.7.0_85
Node.js	0.10.36

The hardware uses Intel Xeon E5-2609 @ 2.40 GHz (4Core) class CPU, 20 GB of memory, 1 TB of HDD, and ETH0 ~ 3 (4Port) of network. Also, the operating system is Linux RedHat Enterprise 6.6 (Santiago), and the Kernel Version is 2.6.32-504.30.3.el6.centos.plus.x86_64. Android devices are used as smart devices, and Android application development tools are shown in Tab. 3.

In order to realize an augmented reality based underground facility management system, it is necessary to display and identify underground objects such as waterworks and sewerage on a public map.

Table 3 Android application development tools

Development Tools	Android Studio 1.2.2
Using the library	libgdx
Android Target	Android KitKat 4.4
JRE	v1.8.0

The underground facilities management system developed in this paper processes the data by using the markerless method depending on the absolute coordinates of the device. Therefore, the accuracy of the data due to the GPS error did not meet the expectations. In order to secure these problems, the way of expressing the ground facilities was changed to the marker type. In addition, the facility that can be visually identified is changed by a marker method so that the device camera can confirm the information of the facility when the facility is moved into the screen. Also, the underground facility renders a line of a desired radius by using GIS coordinate information, and changes the view point to move using the GPS and the sensor of the device. Therefore, it will be possible to develop an engine that can check and use the data in a precise error range when developing the engine through the marker method and the actual mapping. Fig. 8 shows the user interface function.

1. Update GPS coordinates
2. Activate MINI MAP VIEW.
3. Activate the supported functions in that mode.
4. Index the displayed information on the screen.
5. Switch AR/MAP mode.
6. Select and display underground objects.

Figure 8 User interface mode

Fig. 9 shows the facility indexing function. The colour and shape of the facility can be checked.

- Facility History Management: Register facility history.
- Facility history: You can check the facility history
- Refresh current location: Refresh all data by current location
- Map data update: Sets and applies the display radius of facility information.
- Address search and move: Update location and data using old address and new address.
- Manual Position Correction: Fix position using map.

Figure 9 Facility indexing function

The underground facility management system procedure is as follows. First, the smart device network connection and DB server connection checking are performed. If both conditions are met, the current position is taken. Move the map to set and confirm the correction for the initial coordinates. When checking, store the index of the position specified in the device memory. You can select either AR mode or Google Map mode to select the entry mode, and change the mode after entry.

In the selection mode screen, select the rendering category, and in summary, identify the facilities in the augmented reality mode through the color and shape of the graphic.

- Facility history: You can check the history list of facilities.
- Facility history registration: You can register history of facilities.

- Manual position compensation: The applied position can be compensated.

Fig. 10 shows the underground facility management screen in 2D mode.

Figure 10 2D mode display

Finally, the developed underground facility management system processed data in a markerless manner, absolutely relying on the coordinates of the device. Therefore, the accuracy of the data due to the GPS error was rather low. In order to secure this problem, the expression method for the ground facilities was changed to the marker method, and the marker method was applied to the facilities that can be identified with the naked eye. In addition, when the device camera moves the corresponding facility into the screen, it is changed so that information about the facility can be checked. The underground facility was changed to use the GPS and sensor of the device to move the viewpoint after rendering a line with the radius desired by the user using the GIS coordinate information. Therefore, it was possible to confirm and use data within a sophisticated error range through the development of the engine through the marker method and actual measurement mapping.

Figure 11 AR mode display

Also, in modifying and improving functions for major maps, 2D MAP Mode was developed with additional functions based on Google Map Android API. Currently, the open API supports general map function and basic GIS data output method, so there are many restrictions in implementing functions other than data output. It was difficult to check the desired facility information when the event was not supported for the constant line and duplicate markers were displayed on the same coordinate line. Therefore, it was developed so that users can check the facilities they want by adding a list where they can check the markers. In addition, in order to check the attribute information of the water supply pipe, the marker was selected and confirmed in the same way as the valve. In order to improve the user's convenience, the function has been improved so that the information is displayed when the desired water supply pipe is selected, rather than the method of checking information by selecting a marker. Fig. 11 shows the underground facility management screen in AR mode.

5 CONCLUSIONS

In recent years, there has been a growing interest in the causes and responses of the ground subsidence in urban areas. The causes of subsidence are subsidence due to lowering of groundwater level, subsidence due to sewage pipe damage, and inadequate soil excavation. Especially, the ground subsidence caused by the sewage loss and excavation work which occur frequently in the urban area is caused by the loss of the soil caused by the damage of the wreckage or by the formation of the empty space in the ground when constructing the underground structure such as the tunnel. There are many cases that are caused by human activities, not by the people.

In order to solve these problems, the need for fusion research is increasing. First, it is necessary to develop an integrated solution that can link the risk index of underground facilities through integrated management of underground space including underground facilities, ground, and underground structure information. This enables realtime monitoring of leak location recognition, continuous leak detection, and groundwater variation monitoring. Finally, an underground space risk prediction system is constructed to provide an urban space underground space risk index, and risk facilities can be preemptively responded to underground space risk through preliminary inspection and response.

This paper was conducted to developed a systematic management system for underground facilities by applying augmented reality technology. To do this, the author used Map API and JSON communication technique. Augmented reality-based underground facilities management system is a system that can locate and modify the location without drawing in the field by communication between tablet and server in relation to underground objects. The augmented reality engine of underground facility management system implemented in this paper is LibGDX sub desktop or mobile platform game engine. The author confirmed the limitations of the data base and GIS program due to limitations of the LibGDX engine. In order to reduce the constraints on scalability and data mapping, research and development of proprietary augmented reality engines is required instead of existing open source engines. Finally, it is possible to precisely measure underground facility survey and condition for existing buried pipe or new public pipe by applying augmented reality based underground facility management system. In addition, it is possible to derive accurate prediction data for underground facilities by performing pipeline information digitization and detailing, and database information of property information to perform information inquiry, editing, and attribute information management.

Finally, through the AR-based underground facility management system implemented in this paper, various expected effects can be derived compared to the existing facility management system. First, it is expected that the period required for analysis, design, development, and implementation necessary for the development of an underground facility management application program will be shortened by using the basic design document. Therefore, each local government can establish the necessary management system within a shorter period of time. Second, the consistency of water and sewage management tasks of each local government can be maintained as the program is produced according to the basic design defined up to the main components of the user interface. Third, since the basic design is made in consideration of the system's scalability and ease of customization, it is easy to expand the system to the unique requirements of each local government. Finally, it is possible to secure product reliability through the universal program quality certification system, making it possible for each local government to select an application program suitable for the actual situation and build the system.

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