GEO-TAGGED IMAGE ACQUISITION AND MANAGEMENT IN SABO FACILITY INSPECTION

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ABSTRACT

Field-based inspection requires some location-based applications, such as geo-tagged image acquisition, database interface, and navigation. Thus, we focus on ground investigation and inspection using mobile devices. In this paper, we propose and evaluate our location-based investigation application for Sabo facility management.

1. INTRODUCTION

Infrastructure asset management is a framework for achieving sustainable infrastructure, such as roads, bridges, railways, and water treatment facilities. In particular, the control of erosion and sediment is called Sabo. The Sabo is one of significant topics in infrastructure inspection. During infrastructure inspection, we generally refer to the latest inspection documents to determine an inspected position, as follows. First, the structure to be inspected is detected after the inspector's arrival in the inspection area. Next, an inspected point is detected in the structure. Then, the condition of the inspected point is recorded and compared with the latest inspection. After that, a geo-tagged photo is captured at the inspected point. A conventional flow for ground-based infrastructure inspection is shown in Figure 1.

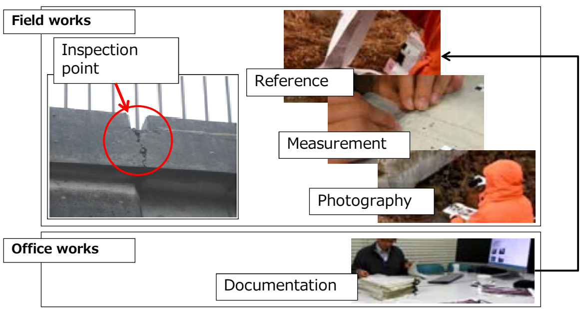

Fig. 1 Ground-based infrastructure inspection

Generally, the management focuses on the low life-cycle cost in a process of construction, maintenance, rehabilitation, and replacement. Based on this framework, a 3D geometric model is often generated based on construction information modeling (CIM). Moreover, asset attributes, such as deterioration, condition, and age are acquired. To check the position of structures and structural elements and collect data related to these structures in frequent monitoring, there is a need to refer to maps, engineering drawings, databases, and technical documents (Garrett et al. 2002). Reliability, completeness, efficiency, and cost are significant indices in monitoring. The reliability, completeness, and efficiency can be satisfied using terrestrial LiDAR, a vehicle-borne mobile mapping system, and aerial photogrammetry using an unmanned aerial vehicle.

In the current state, although 3D scanners can acquire high resolution data, it is not easy to acquire details of asset attributes with 3D measurements. Thus, we focus on ground investigation and inspection using mobile devices (Kamada et al. 2013). Field-based inspection requires some location-based applications, such as geo-tagged image acquisition, database interface, and navigation (Hammad et al. 2006). Mobile devices, such as tablet PCs, smart phones, and global positioning system cameras, have the potential to assist inspectors in infrastructure asset monitoring because of their built-in sensors and components that include cameras, GPS receivers, gyro sensors, Wi-Fi, microphones, speakers, vibrators, and large storage. Therefore, we aimed to assist investigators in infrastructure asset monitoring with location-based applications using mobile devices.

2. METHODOLOGY

Our proposed methodology for location-based infrastructure inspection is described in Figure 2. Our methodology consists of inspection operations with mobile devices and mapping with images to improve conventional inspection approaches.

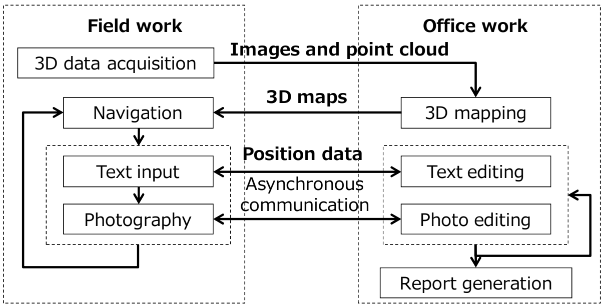

Fig. 2 Proposed methodology

2.1 Mobile inspection application

The functions and performance of infrastructure inspection assistance with a mobile device, such as a tablet PC equipped with GPS, are summarized in Table 1. Category A indicates essential functions and category B indicates additional functions. In addition, we propose a data model for our Web GIS-based mobile inspection application to satisfy the above-mentioned functions, as shown in Figure 3.

Table. 1 Functions and performance of infrastructure inspection assistance with a mobile device

Category A	·Display of maps, drawings, images, movies, and technical information ·Input of characters, lines, and shapes ·Adding a postscript to technical documents
Category B	·Documentation compatible with various template sheets ·Display of various types of maps and drawings (tiff, shp, sxf, dwg, etc.) ·Navigation in facility area ·Measurement (distance and area, etc.) ·Change detection ·User intuitive operability

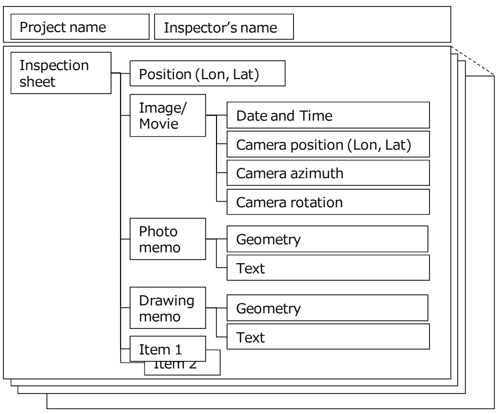

Fig. 3 Data model for our Web GIS-based mobile inspection application

An inspection work is subdivided into several activities, such as geotagged image acquisition, adding a postscript to a photo, and adding a postscript to an engineering drawing. Geotagged data generated from these works are managed with Extensible Markup Language to automate file export using an inspection template prepared by municipalities and a combination of managed data, such as maps, images, and movies, using position data as a retrieval key in inspection navigation. Acquired GPS data are mainly used for the management of location and time data. The location data included represent the position of structures, camera position data, and camera azimuth and rotation data.

2.2 Location data management

The required positioning accuracy is dynamically changed by each inspection work. For example, a closed photograph requires the same position (with approximately 1 cm accuracy) and direction (with approximately 1 degree accuracy) in the latest inspection to achieve automation of image registration for detection of any change in an infrastructure inspection (Nakagawa, Katuki, Isomatu and Kamada, 2013). On the other hand, inspection point detection requires lower positioning accuracy, from approximately 10 cm to 1 m. Moreover, in structure detection, positioning accuracy is allowed to be approximately 10 m. In addition, 100 m positioning accuracy is sufficient for an inspector's arrival in an inspection area. Thus, a definition with several steps or spatial resolutions is effective in location data management. In this research, these steps are represented as levels of details (LODs), such as LOD1: address, LOD2: structure, LOD3: inspection point, and LOD4: photography, as shown in Table 2.

Table. 2 LODs in infrastructure inspection

Levels of details	Content	Required accuracy
LOD1 **Address**	Inspector's arrival in an inspection area	100m
LOD2 **Structure**	Structure detection	10m
LOD3 **Inspection**	Inspection point detection	10 cm – 1 m
LOD4 **Photo management**	Documentation - Photography - Drawing	- 1 cm - 1 degree

3. EXPERIMENT

We conducted experiments involving the daily and annual Sabo infrastructure inspection work in a sediment-retarding basin consisting of dikes, bridges, and debris barriers in Fukushima, Japan (see Figure 4).

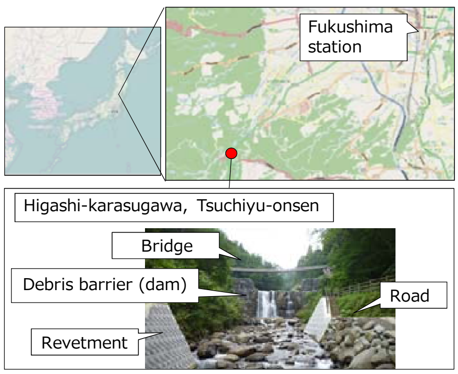

Fig. 4 Study area

In attribute data acquisition, we record conditions of infrastructures, such as cracks, damages and displacements, based on checklists distributed by Japanese Ministry of Land, Infrastructure, Transport and Tourism (MLIT). We assigned these checklists to meta-data and main data, as shown in Figure 5. Then, we input text data and images to record the conditions of infrastructures with some mobile devices, as shown in Figure 6.

Meta data

- Identifier
- Project name
- Address
- Region's name
- Office's name
- Inspector's name
- Weather
- Date
- Time

Main data

- The degree of emergency (A,B,C or D)
- Checklists

__砂防指定地__

1. 工作物の新築，改築，移転又は除却
2. 土地の掘削，盛土，切土等の形状を変更する行為
3. 土石又は砂れきの採取，集積又は投棄
4. 立木竹の伐採
5. 樹根，芝草又は埋もれ木の採取
6. 木竹，土石等の滑下又は地引きによる運搬
7. ゴミ，産業廃棄物等の不法投棄
8. 指定地標識の有無
9. 指定地標識の発錆による劣化等の変状
10. 流域の荒廃
11. 山腹の崩壊
12. 地すべり等の変状
13. 流域の倒木
14. 渓床への不安定土砂の蓄積
15. その他（　　）

__えん堤工__

1. 堤体の破損
2. 堤体のクラック
3. 堤体の漏水
4. 堤体の変位
5. 周辺地山の崩壊
6. 周辺地山の漏水
7. 周辺地山の地すべり等の変状
8. 基礎地盤の洗掘
9. 基礎地盤の変位
10. 土砂の異常堆砂
11. 魚道の破損
12. 防護柵等の付属施設の破損
13. その他（　）

__床固工__

1. 床固の破損
2. 床固のクラック
3. 床固の変位
4. 土砂，枯れ草等による流下能力の低下
5. 魚道の破損
6. 防護柵等の付属施設の破損
7. その他（　）

__護岸工__

1. 護岸の開口、破損
2. 護岸のクラック
3. 護岸の沈下，吸い出し等の変状
4. 根入れ部の洗掘等の変状
5. 土砂，枯れ草等による流下能力の低下
6. 防護柵等の付属施設の破損
7. その他（　）

__親水設備工__

1. 親水設備の開口、破損
2. 親水設備のクラック
3. 親水設備の沈下，吸い出し等の変状
4. 根入れ部の洗掘等の変状
5. 高水敷の陥没等の変状
6. 深い淵，急流の瀬等，危険性の高い河川の変状
7. 防護柵等の付属施設の破損
8. 標識，看板等の破損
9. その他（　）

__管理用道路__

1. 開口，陥没等の変状
2. 雑草の繁茂
3. その他（　）

Fig. 5 Checklists in structure inspection based on MLIT's guidelines

	**YOGA TABLET 8** - Android - CPU:1.2 GHz - RAM: 1 GB - 1280×800 px - GPS, Acceleration, Gyro, Compass
	**Xperia Z2 Tablet** - Android - CPU:2.3 GHz - RAM: 3 GB - 1920×1200 px - GPS, Acceleration, Gyro, Compass
	**iPad 1st** - iOS - CPU:1 GHzB - RAM:256 MB - 1024×768 px - Acceleration , Compass
	**Xperia VL** - Android - CPU:1 GHz - RAM: 16 GB - 1280×720 px - GPS, acceleration, gyro, compass

Fig. 6 Mobile devices (tablet PCs, smart phone)

In addition, omni-directional and close-range aerial images are also acquired to record attribute data of the conditions of infrastructures. These images are used to improve the integrity in infrastructure inspection with augmented reality applications in office works.

We used two types of cameras, such as THETA m15 (RICOH) and QBiC PANORAMA (Elmo), to acquire the omni-directional images. These cameras were mounted on a monopod, as shown in Figure 7 and Figure 8. We also used a GPS logger (N-241, HOLUX) to get position data with omni-directional images. Acquired omni-directional images were stitched to be panoramic images and movies. These images and movies are viewed with a head-mount display (Oculus Rift), as shown in Figure 9. Moreover, we used a micro drone to acquire close-range aerial images with GPS/IMU data, as shown in Figure 10.

Fig. 7 Panoramic video camera (THETA, RICOH)

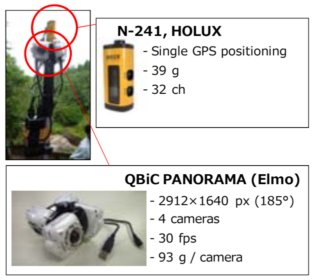

Fig. 8 Panoramic video camera (QBiC, ELMO)

Fig. 9 Head-mount display (Oculus Rift, Development Kit 2)

Fig. 10 Micro drone (Bebop drone, Parrot)

4. RESULT

In our experiment, 213 images were acquired with mobile devices. Using geo-tag data, these images are reverse-geocoded into a map with GPS position data, as shown in Figure 11.

Fig. 11 Geotagged images

Then, acquired images are grouped into 36 viewpoints. In a manual work, it took 3120 sec. On the other hand, it took 4 sec in our position and azimuth filtering. Therefore, we confirmed that our application drastically shorten a work time for the image retrieval, as shown in Figure 12.

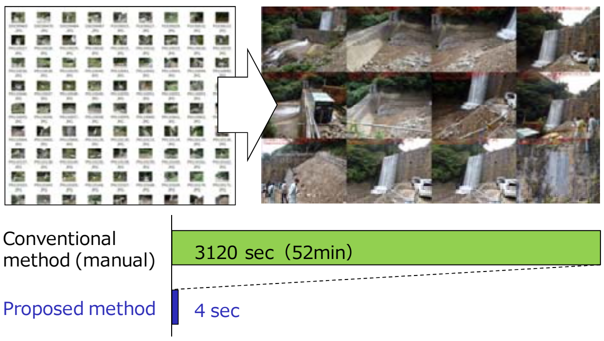

Fig. 12 Position and azimuth filtering result

5. DISCUSSION

Positioning from LOD1 to LOD3 requires from 100 to 1 m accuracy. Thus, single GPS positioning is suitable for position data acquisition. However, LOD4 requires 1 cm accuracy with precise positioning, such as a real-time kinematic GPS (RTK-GPS). Generally, low-cost inspection restricts the use of expensive devices such as an RTK-GPS. In low-cost inspection, the performance of satellite positioning is generally improved by assisted-GPS, differential GPS and multi-GNSS positioning using GPS, GLONASS, and QZSS. Data fusion of GPS and dead reckoning also improves the performance of positioning. However, although these approaches improve availability, they have almost no effect on positioning accuracy improvement. In this research, satellite positioning was assumed to have 1m accuracy, even if we could apply improvement approaches to positioning accuracy. Thus, a location data management approach using movies was applied in LOD4 (precise positioning). This approach assists inspectors to determine a position in a photography using a movie that was captured in the latest inspection and the attached approximate position data acquired with GPS.

We qualitatively confirmed that automation of location and time data recording is more reliable than manual paper-based recording in infrastructure inspection. On the other hand, paper-based recording offers an advantage for documentation in an outdoor location, because text input with a mobile PC is time-consuming work. Moreover, we confirmed that raindrops worsen the performance of the touch interface, even when a waterproof tablet PC is used.

Position data acquisition depends on single GPS positioning. Although our study area consisted of open-sky environments and structures, GPS positioning was insufficient for positioning in LOD3 (inspected position detection) in an area surrounded by mountains or under a bridge. On the other hand, we have confirmed that geotagged movie was effective in estimating the LOD3 and LOD4 position data. Even if position data included a positioning error caused by low dilution of precision and multipath transmission, an inspection position could be detected using movie guidance. Moreover, we could also focus on geotagged omni-directional camera data to detect an inspected position.

In addition, we confirmed that inspection work using a tablet PC held with both hands was dangerous on bad roads, in riverbeds, and in craggy places. Therefore, we would propose to use hands-free applications using wearable devices and voice-guided applications with geofencing techniques to improve safety in inspections using a mobile device.

CONCLUSION

In this paper, we focused on ground investigation and inspection using mobile devices. We aimed to assist investigators in infrastructure asset monitoring with location-based applications. We proposed and evaluated our location-based investigation application for facility management based on CIM. Through our experiment, we explored several issues in infrastructure asset monitoring using mobile devices. Integrity in positioning should be improved to achieve more reliable and effective inspection works. Therefore, we proposed an LOD definition for positioning data management in inspection works. Moreover, we proposed combinations of base maps and several types of data acquired with a mobile device in inspection works to improve reliability, completeness, and integrity in positioning.

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