



Attribute Assignment to Point Cloud Data and its usage

By Yoichi Fujita, Yuji Hoshino, Seigo Ogata & Ichiro Kobayashi

Kumamoto University, Japan

Abstract- In recent years, with the development of laser measurement technology, utilization of point cloud data is progressing. However, since point cloud data does not contain attribute information, the usability of the data is low. It is possible to consider that by assigning attributes to the non-attribute point cloud data, this can lead to the usage of point cloud data in each phase of life cycle of construction: design, construction, and maintenance. Therefore, in this paper, the authors have proposed an attribute assignment method for point cloud data. In addition, the authors proposed the way to use attributed point cloud data, the usage as objects, data linkage, and visualization by using the attribute assignment method. Point cloud data of a dam was used as a case study for the proposed method and the usage.

Keywords: *point cloud data, attribute assignment, usage of point cloud data, visualization, data linkage.*

GJCST-B Classification : C.2.1, C.2.4



ATTRIBUTEASSIGNMENTTOPOINTCLOUDDATAANDITSUSAGE

Strictly as per the compliance and regulations of:



RESEARCH | DIVERSITY | ETHICS

Attribute Assignment to Point Cloud Data and its usage

Yoichi Fujita^α, Yuji Hoshino^σ, Seigo Ogata^ρ & Ichiro Kobayashi^ω

Abstract— In recent years, with the development of laser measurement technology, utilization of point cloud data is progressing. However, since point cloud data does not contain attribute information, the usability of the data is low. It is possible to consider that by assigning attributes to the non-attribute point cloud data, this can lead to the usage of point cloud data in each phase of life cycle of construction: design, construction, and maintenance. Therefore, in this paper, the authors have proposed an attribute assignment method for point cloud data. In addition, the authors proposed the way to use attributed point cloud data, the usage as objects, data linkage, and visualization by using the attribute assignment method. Point cloud data of a dam was used as a case study for the proposed method and the usage.

Keywords: *point cloud data, attribute assignment, usage of point cloud data, visualization, data linkage.*

I. INTRODUCTION

With the development of Global Positioning System (GPS) and 3D laser scanners, fixed laser survey equipment and MMS (Mobile Mapping System) have been devised and are currently deployed for actual data acquisition. However, the acquired data is used only as point data (e.g. as management information) and as the conversion to 2D drawing. In recent years, the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) has announced the implementation of CIM (Civil Information Management/Modeling)—which is a civil version of BIM (Building Information Management)—in loads of major projects around Japan while establishing the field of architectural design. CIM has applied the concept of sharing, using, and developing 3D models in each phase of the life cycle of construction—planning, design, construction, and maintenance. CIM is primarily aimed at improving the construction production process. The use of 3D data in the design phase is expected to advance rapidly.

Thus far, the authors have conducted numerous research studies regarding the use of point cloud data. The proposals include the utilization of point cloud data in road space using editing method and attribute assignment to point cloud data. This development

allows for a number of possibilities in using the point cloud data at each stage of the life cycle of construction solely. Other researchers also proposed the use of point cloud data. For instance, Mizoguchi et al. has proposed evaluation method for scaling of bridge piers using point cloud data. What's more, Yun, H et al. has proposed a method for pavement maintenance using the data derived from MMS. Therefore, it can be presumed that the utilization of point cloud data is smoothly progressing.

In the present paper, the authors have proposed an attribute assignment method for point cloud data in order to expand the range of point cloud data utilization. Additionally, the authors have shown how to use the attributed point cloud data. By assigning attributes to point cloud data, it is possible to use point cloud data as objects, data linkage, and visualization. There are hence various possibilities in using point cloud data, not limited to road space only. In chapter 2, the authors described the significance of assigning attributes to point cloud data. In chapter 3, the authors illustrated the attribute assignment method and the usage of attributed point cloud data. In chapter 4, the author measured the usage of attributed point cloud data using point cloud data of dam as case study. The results are subsequently discussed.

II. ATTRIBUTES OF POINT CLOUD

a) *The significance of attribute assignment*

When point cloud data is given attributes, its use has become more intensive. For example, consultation and examination of a project becomes possible by giving attributes to an unnecessary place in the reconstruction site, removing the data from point cloud data, and adding new structures. Furthermore, by classifying each structure existing in the area surrounding the roads, point cloud data are then deployed in relocation and removal plans. The attributed point cloud data containing additional information—volume, damage, pictures, documents—can be used in the management of the existing structure. Specifically, it is possible to acquire the data of the existing structure using laser scanner equipment. Since the point cloud data of the structures are directly available, the data is deemed practical in existent structure management. Such use leads to reduction in labor and costs of CAD 3D modeling.

Author α σ ω : Graduate School of Science and Technology Kumamoto University, Japan. e-mails: fujitay@kumamoto-u.ac.jp, hoshino@kumamoto-u.ac.jp

Author ρ : author Technology Research Department, Advanced Construction Technology Center, Tokyo, Japan. e-mail: ogata@actec.or.jp

b) *The attributes of point cloud data*

In the analysis of numerical information of the point data, it becomes possible to classify and determine the point cloud data as a "group". The authors described the analysis of typical information of point data as shown below:

i. *Position information*

By setting the values for each of the position information (x, y, z), it is possible to extract the planes along the three axes. For example, gradient tints diagram can be created by coloring the elevation values as seen in figure 1. For this data, it is possible to extract the data that has the same elevation with z value by setting the threshold value of z value. The shape analysis of the structure for the relative position between the dots can be performed. On top, extraction is possible by visually specifying the range and the location.

ii. *Reflection intensity*

When the threshold value to the reflection intensity of the measured data is set, structures can be classified depending on types of materials. Figure 2 is an example, where the outer wall of a building and the white line inside of point cloud data are extracted. A portion of road surface can also be extracted as seen in figure 2 b).

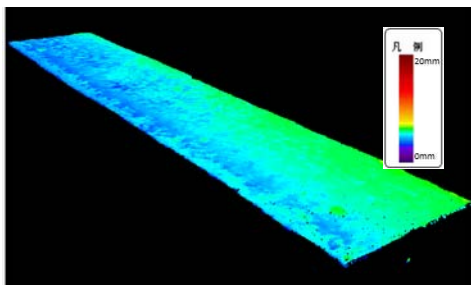
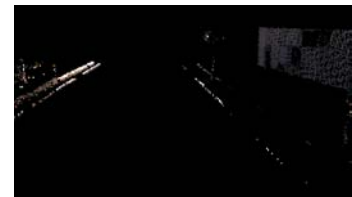


Fig.1. Position Information

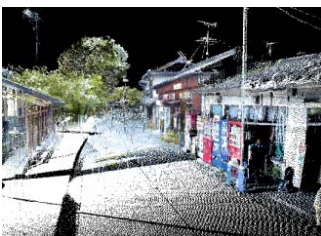


a) Original data

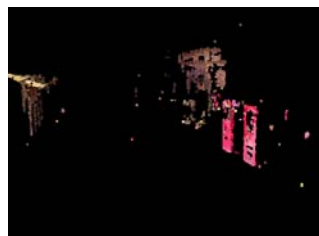


b) Extracted data

Fig.2. Reflection Intensity



a) Original data



b) Extracted data

Fig.3. Color Information

iii. *Color information*

Classification of colors can be made by setting the threshold value and combining the three elements (r, g, b) of color information from the measured data. Figure 3 exemplifies red point extraction from point cloud data. Figure 3 b) shows how the objects containing red color are extracted. Furthermore, When

RGB color information is converted into HSV color, it is possible to identify the artifact and structures.

c) *The partition of point cloud data*

As described in the previous section, the partition and classification of the point cloud data can be performed by analyzing the attributes of the point data. Additionally, the editor allowing the partition of point cloud data has been developed in the previous studies. With this editor, it becomes possible to split point cloud data into arbitrary shapes. Further, the development of editing software for point cloud data has been encouraged. Such progress leads to the possibility of structure partition and classification based on point cloud data. When the attributes are assigned to the partitioned point cloud data, the utilization of point cloud data is widely increased. In this paper, the authors showed the method in assigning the attributes to the partitioned and classified point cloud data.

III. ATTRIBUTE ASSIGNMENT

a) *Method*

In this section, the authors portrayed the attribute assignment method to the partitioned point cloud data. P represents the whole point cloud data, and p_i represents each point of the point cloud data.

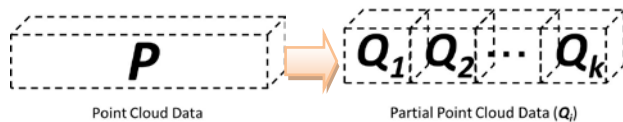


Fig.4. Partition of Point Cloud Data

The formula of the whole point cloud data is as follows:

$$P = \{p_1, p_2, \dots, p_i\} \quad (i = 1, 2, \dots, n)$$

The formula for each point p_i is as follows:

$$p_i = [x, y, z, r, g, b]^t_i \quad (i = 1, 2, \dots, n)$$

Figure 4 shows the partition of point cloud data. Q_i is a portion of point cloud data. q_j represents each point of point cloud data. The formula for the partition is as follows:

$$Q_i = \{q_1, q_2, \dots, q_j\}$$

$$(i = 1, 2, \dots, k)$$

$$(j = 1, 2, \dots, l)$$

The formula for q_j is shown as follows:

$$q_j = [x, y, z, r, g, b]^t_j \quad (i = 1, 2, \dots, l)$$

Therefore, the whole point cloud data P becomes as follows:

$$P = \{Q_1, Q_2, \dots, Q_i\} \quad (i = 1, 2, \dots, k)$$

Next, the ID of Q_i is δ_i , and the formula is as follows:

$$\delta_i = i \quad (i = 1, 2, \dots, k)$$

As a result, the formula of Q_i is shown using ID (δ_i) and each point of q_i as follows:

$$Q_i = [\delta_i, q_j]^t_{ij} \quad (i = 1, 2, \dots, k) \quad (j = 1, 2, \dots, l)$$

r_i is set as the parameter of attribute information, and

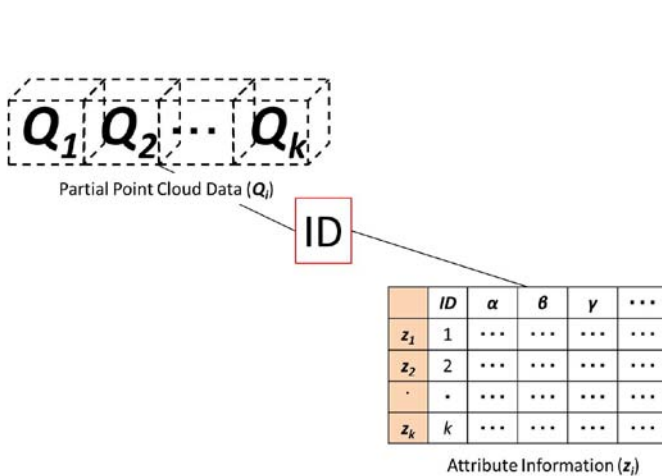


Fig.5. Attribute Assignment

the formula is as follows:

$$r_i = [\alpha, \beta, \gamma, \dots]^t_i \quad (i = 1, 2, \dots, k)$$

The formula for z_i which is the assigned attribute information containing ID (δ_i) and parameter of attribute information r_i is as follows:

$$z_i = [\delta_i, r_i]^t_i \quad (i = 1, 2, \dots, k)$$

The attribute information z_i is assigned to the partition of point cloud data Q_i as shown in figure 5.

The attributed point cloud data is set as Q'_i . By using the partitioned point cloud data Q_i and the attribute information z_i , the attribute assignment equation is represented as follows:

$$Q'_i = \begin{bmatrix} Q_1 & 0 & 0 \\ 0 & Q_2 & 0 \\ 0 & 0 & \ddots \end{bmatrix} \begin{bmatrix} z_1 \\ z_2 \\ \vdots \end{bmatrix} \quad (i = 1, 2, \dots, k)$$

(1)

Thus, it is possible to assign attributes to the partition Q_i of point cloud data.

b) The usage of attribute assigned point cloud data

i. Usage as objects

It is possible to handle attribute assigned point cloud data as CAD objects. The application examples show the possibility of CAD operation (e.g. partition, movement, hidden, coloring, stretching, etc.) within point cloud data. It is possible to classify the facilities in point cloud data. By partitioning the structures and assigning different attributes from Q_1, Q_2, \dots , it is possible to handle many parts as different objects. Consequently, it is possible to apply this method in removal project because the damaged place of a structure can be set as other attributes.

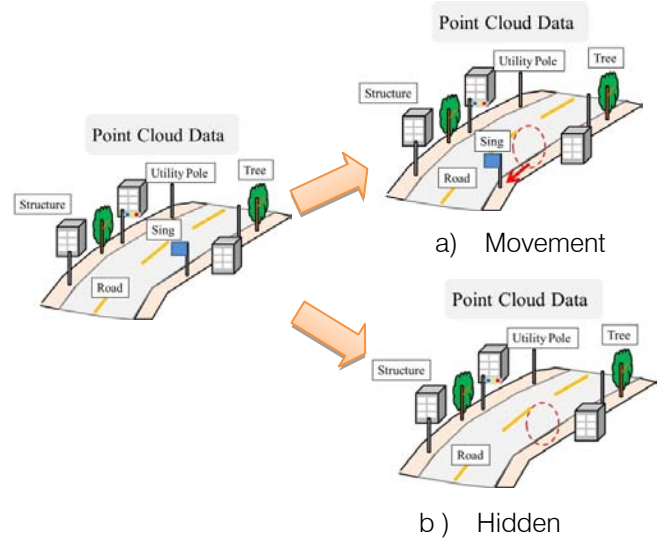


Fig.6. Usage as objects

a. Movement

By moving the partitioned part of individual locations to arbitrary locations, it is possible to check position relationship between the partitioned data and the interference. For example, it is possible to move only the sign as shown in figure 6 a).

b. Hidden and removal

It is possible to validate the changes in the current state when an object disappears because only the partitioned part is removed or hidden. As seen in figure 6 b), it is possible to confirm the situation due to the removal of the sign only.

ii. Consideration according to time axis
 a. Changes in structure

The structure can be hidden and moved along the time axis. This makes it possible to check the behavior of a structure over the time. For instance, in the case of a removal project, it is possible to show the progress of the removal process of the structure. Also, it is possible to check a series of behaviors such as loading of a removed structure to the trailer as shown in figure 7.

b. Confirmation of surrounding environment

Point cloud data can reproduce the targeted site with high accuracy. Due to this fact, it is possible to

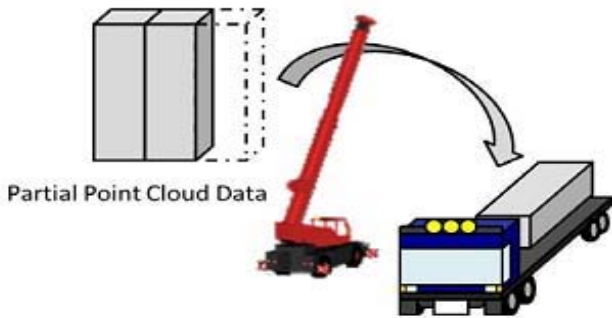


Fig.7. Continuous behavior of loading up a trailer with removal structures.

determine the environment of the site during the consultation and examination of the model space. In construction, when a structure is removed, its immediate environment will accordingly change. For example, there will be additional locations such as the location for heavy equipment and construction location. It is possible to confirm the location of interference—street lights and utility poles—with CAD-created new structures by giving attributes to existent structures in the surrounding when checking the construction process. Particularly, it is possible to check the interference between the removal part and the trees by giving attributes to the surrounding as shown in figure 8.

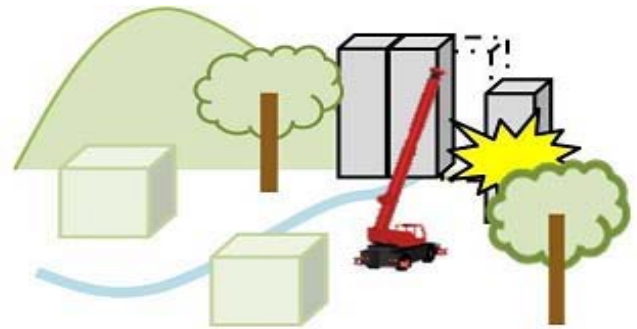


Fig.8. Confirmation of the relation between the surroundings



Fig.9. Data Linkage

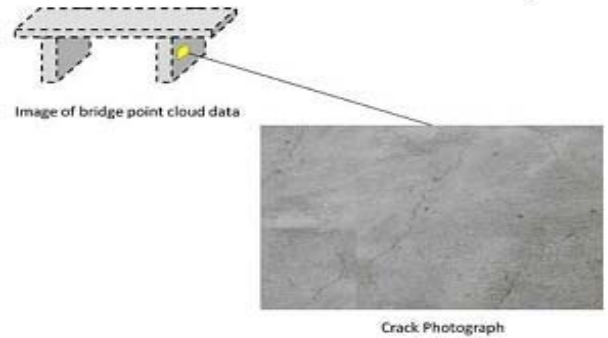


Fig.10. Three-dimensional Position Linkage

iii. Deand visualization

a. Data linkage

Photos, pdf files, and documents such as Excel can be linked to point cloud data as attribute information. For example, figure 9 shows attributed point cloud data of a sign with documents linked into it. Management information and photographs taken during patrol can possibly linked to point cloud data of a facility; likewise, document management and confirmation on point cloud data can be connected. In addition, since point cloud data is a 3D data, it is possible to link any information corresponding to the three-dimensional position. Attributes in point cloud data of the piers can be assigned while maintaining the

elevation of position information. This leads to the determination of crack situation in the piers. Such possibility is shown in figure 10. Point cloud data holds the basis possibility of managing this management information.

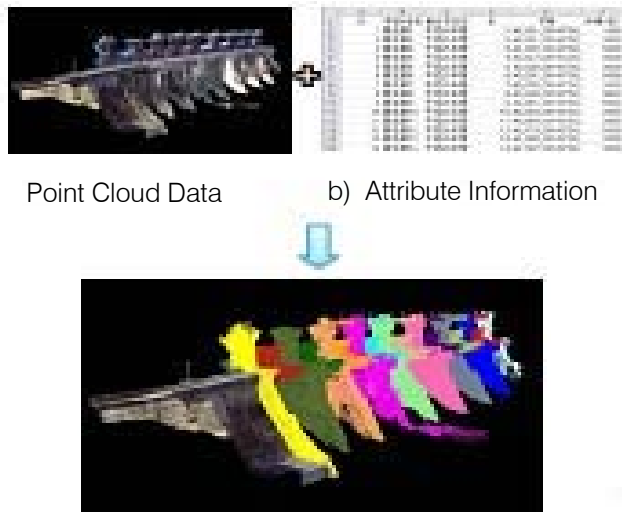
b. Visualization of the attributed information

By adding information to point cloud data, the information on point cloud data can be visualized. Additional information such as spreadsheet, CSV, etc. is also necessary for management. After the information is entered into spreadsheets and the attributes are assigned using equation in 3.1, visualization of the information becomes possible as shown in figure 11. The information is then added to the point cloud data of

First of all, using numerical value base maps and point cloud data of the dam in figure 13, the authors performed the reproduction and determination of the current state and attribute assignment to the body of the dam.

a) *Attribute assignment*

Figure 14 a) shows the partition of measured point cloud data of the dam body according to its removal parts. Figure 14 b) shows the attribute information in Excel, and by using equation (1), the attribute information is assigned to the dam body as shown in figure 14 c). Figure 14 c) illustrates the attribute assignment of the dam body according to removal plans in which each part has different attributes. For that reason, different colors are given to the parts according to the assigned attributes. The time required in editing the point cloud data in this current case study took about 2 hours, and the time required in assigning attributes to the point cloud data took about 5 minutes. By contrast, it took 2 days creating CAD objects. Therefore, it was possible to edit the point cloud data in a very short amount of time.



c) Attribute Assign Data

Fig.14. Attribute Assignment

b) *Used as objects*

By using the attributed point cloud data of the removal parts in figure 14 c), it is possible to check the results of the dam removal plan as shown in figure 15. Figure 15 a) shows the planning drawing paper of the removal plan. Figure 15 b) show the confirmation of removal plan based on point cloud data. As shown in figure 15, confirmation of the removal plan on the drawing paper can be obtained in the same way as confirmation on point cloud data. It tends to be impossible to check the process from the drawing paper; however, point cloud data makes it possible to determine the changes in moving the removal parts and the confirmation of removal process from arbitrary directions.

c) *Display of attribute information*

The result of visualizing the point cloud data which contains attribute information is shown in figure 16. The removal schedule and linked photo data can be confirmed on point cloud data. Giving necessary information to the point cloud data makes it possible to confirm the information while grasping the current state on point cloud data.



a) Planning Drawing Paper

b) Point Cloud Data

Fig.15. Confirmation of Removal Schedule

d) *Visualization of the attribute information*

The result of changing the display date of the assigned attribute information is shown in figure 17. The parts are colored according to the removal schedule of every year and are visualized in order to visually determine the assigned attribute information. With such visualization in figure 17, it is possible to determine the sequential order and the position in removing the parts at a glance.

e) *Discussion*

In this case study, the authors showed the attribute assignment to the body of the dam and the usage of attributed point cloud data. The case study shows three possibilities: 1) usage of point cloud data as objects, 2) confirmation and display of assigned attribute information on point cloud data, and 3) the usage of simulating and determining changes in attribute information visually. With these three possibilities, the utilization of point cloud data has



become widely enlarged. This leads to the advancement in using point cloud data in the consultation and examination during design and construction phases. This progress thus leads to the use of point cloud data in managing structures in maintenance phase. Such advancement can be also considered as labor reserves due to the sole use of point cloud data without the need to create CAD objects. In this case study, attribute assignment is not limited to the body of dam only, but to its immediate environment such as typography, trees, and etc. Since point cloud data can reproduce the current state of the structure while containing the position information, it can lead to the usage in three-dimensional Geographic Information System (GIS) by giving attributes to the point cloud data. There is hence a possibility in using point cloud data in managing more advanced structures and features. Unsolved difficulties in assigning attributes still remain, though. In re-assigning attributes and re-edit point cloud data, re-partition and re-classification is required, resulting in labor problems.

V. CONCLUSION

In this paper, the authors proposed an attribute assignment method to point cloud data and described the usage of attributed point cloud data. In the case study, attributes were assigned to the removal parts of point cloud data of the dam, and the proposed usage was verified. In chapter 2, the authors described the attributes of point cloud data and the significance of attribute assignment. In chapter 3, the authors proposed a method in assigning attributes to point cloud data and described possibilities for usage of attributed point cloud data. In chapter 4, the measured point cloud data of the dam was partitioned into arbitrary shapes. Deploying the attribute assignment method proposed in chapter 3, the authors were able to assign the parts with different attributes. Finally, the authors examined the possibilities of visualization and display of information and the usage of point cloud data as objects using the attributed point cloud data.

For future prospects, the authors plan to reply to the problems mentioned in the discussion section.

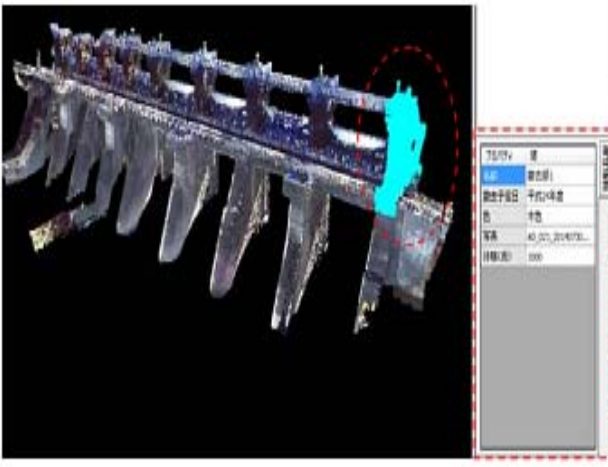


Fig.16. Information Confirmation on Point Cloud Data

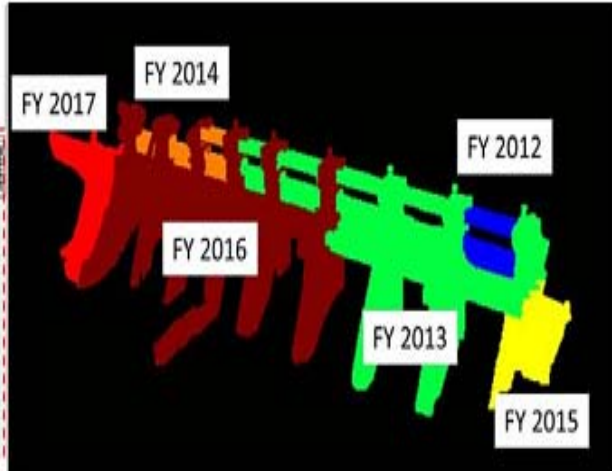


Fig.17. Visualization of Information

VI. ACKNOWLEDGEMENT

The authors would like to express their gratitude to ITOCHU Techno-Solutions Corporation, Informatics Autodesk Co., Ltd, and Kumamoto Prefecture Enterprise Bureau for providing precious data to this study.

REFERENCES RÉFÉRENCES REFERENCIAS

1. Fujita Y., Kobayashi I., Ogata S., Chanseawrassamee W. (2014). Development of Point Cloud Data Editor and its Applications, *Journal of Japan Society of Civil Engineers, Ser. F3 (Civil Engineering Informatics)*, 70 (1), 48-55.
2. Fujita Y., Kobayashi I., Hoshino, Y., Chanseawrassamee W. (2014). Development of Attribute-Assign-Editor for Road Surface Point Cloud Data, *International Journal of Engineering and Technology (IJET) (ISSN: 1793-8236)*, Volume8 Number3, 170-176
3. Fujita Y., Ogata S., Chanseawrassamee W., Kobayashi I. (2014). Attribute Assigned Road Point Cloud for Using in Construction Life Cycle, *Journal of Japan Society of Civil Engineers, Ser. F3 (Civil Engineering Informatics)*, 70(2), 144-151.

4. Mizoguchi, T., Koda, Y., Iwaki, I., Wakabayashi, H., Kobayashi, Y., Shirai, K.,...Hara, Y. (2012) Quantitative Scaling Evaluation of Road Bridge using Terrestrial Laser Scanner, *Proceedings of Civil Engineering Informatics Symposium*, Vol. 37, 61-64.
5. Guan, H., Li, J., Yu, Y., Chapman, M., Wang, H., Wang, C., Zhai, R. (2015). Iterative Tensor Voting for Pavement Crack Extraction Using Mobile Laser Scanning Data, *IEEE Transactions on Geoscience and Remote Sensing*, 53(3), 1527-1537.
6. Tanahashi, T., Sada, T. (2012). Study on Practicability of Road Alignments estimation using Reflection Intensity Data of Air bone Lidar, *Proceedings of the Japan Society of Photogrammetry and Remote Sensing*, 87-90.
7. Kobayashi, I., Fujita, Y., Sugihara, H., and Yamamoto, K. (2011). Attribute Analysis of Point Cloud Data with Color Information, *Journal of Japan Society of Civil Engineers, Ser. F3 (Civil Engineering Informatics)*, 67(2), 95-102.

