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# Toward an Environmental Database

## *Exploring the material properties from the point cloud data of the existing environment*

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*The utilization of point cloud as a 3D laser scanning product has reached across multi-disciplines in terms of data processing, data visualization, and data analysis. This study particularly investigates further the use of typical attributes of raw point cloud data consisting of XYZ (position information), RGB (colour information) and I (intensity information). By exploring the optical and thermal properties of the given point cloud data, it aims at compensating the material and texture information that is usually remained behind by architects during the conceptual design stage. Calculation of the albedo, emissivity and the reflectance values from the existing context specifically direct the architects to predict the type of materials for the proposed design in order to keep the balance of the surrounding Urban Heat Island (UHI) effect. Therefore, architects can have a comprehensive analysis of the existing context to deal with the microclimate condition before a design decision phase.*

**Keywords:** *point cloud data, material characteristics, albedo, emissivity, reflectance value*

### INTRODUCTION

The utilization of point cloud as a 3D laser scanning product has reached across multi-disciplines in terms of data processing, data visualization, and data analysis. In engineering domain, for example, it is predominantly used for surveying and mapping or modelling the construction project like dam or road surface (Fujita et al. 2014). It also starts taking over the building scale by performing further the 3D reconstruction of the mechanical, electrical, plumbing (MEP) in the building system (Shih 2002). White (2013) specifically pointed out that point cloud stands as a discrete three-dimensional location that can have additional metadata associated with each record. According to Feng (2012), the metadata properties, later the so-called attribute information of point cloud may deliver four functions of information: geometrical information (size, roughness), physical information (mechanical properties, physical identity), visual information, and spatial information (position and orientation).

Drawing the above considerations, we can identify the potential application of point cloud data which not only corresponds to a data representation but also drives further into the performance analysis in architecture. This study particularly investigates further the use of typical attributes of point cloud consisting of XYZ as position information, RGB as colour information and I stands for intensity information (Weinmann 2016). Kobayashi et al. (2011) employed the colour information of point cloud to detect the road signage in Japan by calculating the Hue (H) and Saturation (S) values of the given RGB colour. Meanwhile, the intensity information can be used to identify the cracks of damaged concrete in the tunnel or caused by natural disaster (Kashani et.al 2015). The position information automatically attached to both colour and intensity values for marking the coordinate locations of each point.

The use of these attributes attempts to address a blank spot in the site analysis of the existing environment. By exploring the optical and thermal properties of the given point cloud data, it aims at compensating the material and texture information that is usually remained behind by architects during the conceptual design stage. Further, calculation of the albedo, emissivity and the reflectance values from the existing context specifically direct the architects to predict the type of materials for the proposed design in order to keep the balance of the surrounding Urban Heat Island (UHI) effect. Therefore, architects can have a comprehensive analysis of the existing context to deal with the microclimate condition before a design decision phase. Of importance factor is keeping the mutual relationship between the new building design and its surrounding environment.

This paper is then formulated into several parts: Part 1, it contains the overview of addressing the point cloud data attributes into the architectural design phase. Part 2 describes a dataset collection. In Part 3, the proposed method and its application into the architectural context. Part 4 contains the result and discussion of the material database.

## DATASET COLLECTION

This study demonstrated a small sample of datasets to run the proposed workflow (see Fig.1). The dataset comprises a small portion of building facades from the data scanning of the Middlestum Church in Groningen, Netherlands. This dataset was collected by using Faro Focus 3D laser scanner with wavelength 950 nm and coupled with a Nikon D5300 to proceed the colour points. The collected dataset used Terrestrial Laser Scanning (TLS) technique so that the material and texture representation of the real context can be accurately visible in comparing with the dataset from Airborne Laser Scanning (ALS) technique. The TLS dataset also allows the architects to capture an isolated place like underground, interior or building areas located under the dense tree's canopy.

Furthermore, this study focuses on exploring the information of XYZ, RGB and Intensity values contained in the raw dataset. Having set these attributes, the proposed procedure in this study is possible to be implemented in another case.

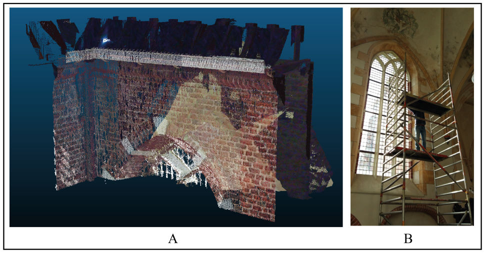



Figure 1
The 3D point cloud datasets: A (cropped facades of Middlestum Church) and B (3D scanning process on site)

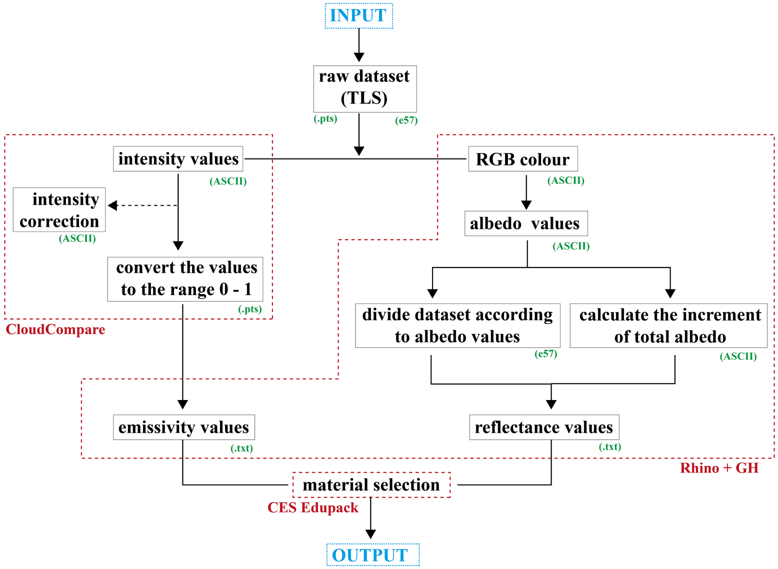
## METHOD

In order to map the material database of the existing environment, the proposed method in this study lies in the two main investigations: the thermal properties and the optical properties. The steps of each procedure are illustrated in Fig. 2.

### *Thermal Properties*

Investigation of the thermal properties refers to the emissivity parameter which constitutes a measure of the heat radiation emitted by the surface of the material (Ashby et, al 2008). It is important to note that the emissivity is not only depending on the material but also on the nature of the surface. In this case, the black body will be assigned for 1.0 emissivity value. Principally, the emissivity shares the similar direction with the intensity information contained in the point

Figure 2
The overview of the proposed workflow



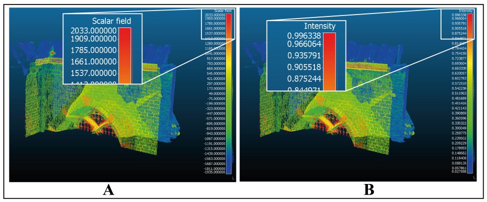

cloud data. The intensity attribute constitutes the amplitude of the return signal which refers to the laser beam that bounces back from the scanned object (ArcGIS 2016). Accordingly, both the emissivity and intensity consider the material properties of the object's surface to record their values although it works inversely (see Fig.3). The intensity values assign 1.0 on the white/bright surface. Thus, we should assign the intensity values of raw point cloud data the other way around to set the correct values of the thermal property.

Before proceeding the intensity values into the thermal properties, the data representation of the intensity should be checked first. It aims at identifying what level of intensity correction is needed. According to the level of intensity processing (Kashani et al. 2015), the dataset only requires Level 0 which is checking the format of intensity. This is because the intensity properties of the dataset correspond already with the correct areas such as the high values refer to the bright and smooth surfaces. In this case, we convert the intensity values of the dataset into range 1.0 in order to match with the input requirement of the thermal properties. The conversion process is necessary due to different format produced by the 3D scanning tools. In Figure 4 below depicts the alteration of colour values from range 0 - 2048 (shown in Figure 4A) into the range 0 - 1 (shown in Figure 4B).

Figure 3
The comparison between intensity values and emissivity values

| Surface color | Intensity (I) | Emissivity (E) |
|---|---|---|
| White | 1.0 | 0.0 |
| Black | 0.0 | 1.0 |

Figure 4
The intensity correction of the dataset: A (before) and B (after)



### *Optical properties*

The section of optical properties corresponds to the reflectivity parameter. The reflectivity stands for the amount of reflected light from the material related to the total of incident light that reaches the surface of the material (Ashby et, al 2008). In order to get the value of reflectivity, the reflectance should be calculated first. Calculation of these parameters requires the RGB colour as the main input. In this case, we only account the reflectance values in the given dataset according to the opaque material properties.

In parallel, we also calculated the albedo values to identify the percentages of the global reflection coefficient in the surface material. It is done by computing the average values of RGB colour for each point contained in the datasets. Afterwards, the generated albedo (in the format of ASCII) can be aligned with the geometrical 3D point cloud (in the format of e57) to detect the designated areas. In the broader urban context, the possibility of calculating the increment of global albedo is available in accordance with the surface distribution of each urban element.

## COMPUTATIONAL WORKFLOW

In general, this study consists of three phases of data processing coupled with its digital tools. First, dataset collection. This phase aims at processing the raw dataset and preparing it in order to be legible in the 3D modelling tools. The tasks specifically include filtering the outlier, cropping the designated areas, activating and checking the scalar field of intensity values, merging the partial data scanning, and exporting the dataset into the format e57 and ASCII. These tasks are supported by using Cloud Compare (CC).

Second, calculation of the attribute properties. Due to a significant amount of point data, the selected dataset is divided into two format. It uses e57 format for handling the geometric of 3D point cloud and ASCII format for adjusting the values of each attribute. The ASCII format is then used to calculate the albedo and the reflectance values. This phase employs Rhino and Grasshopper components.

Third, the material selection. This phase aims at identifying the type of the material according to albedo, emissivity, and the reflectance values. The selected values are then inputted into the CES Edupack to filter the matched material.

## RESULT AND DISCUSSION

As the result of this study, we presented the following three items:

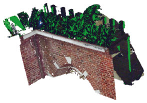
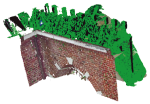
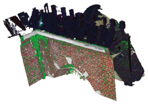
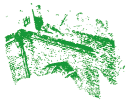
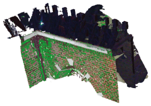
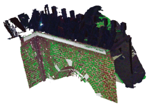
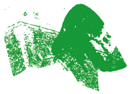
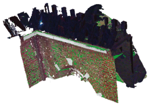
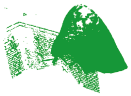
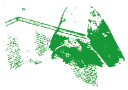
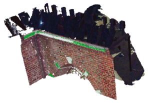
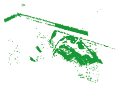
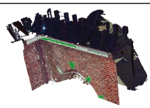
First, we segmented the areas based on intensity values in order to identify the surface distribution in the dataset (see Fig. 5). The selected areas are then converted into the emissivity values. It is useful for identifying the material characteristics in terms of thermal properties.

The Figure 5 illustrates that the largest portion captured in the intensity is shown in the range between 0.2 - 0.3 (40.7%). It refers to space in-between the exterior and interior wall of the Church. According to the intensity properties, the selected areas indicate a rough surface with a diffuse reflection and less glossy surface. It can be proved by observing the color of the areas and its location which is difficult to reach by the 3D scanner. This area, consequently, shows a massive noise of points and undefined geometrics. On the other hand, the characteristics of this area correspond to the range 0.8 - 0.9 of emissivity values.

The least portion of intensity is demonstrated in the range 0.8 - 0.9 for only about 0.7 % of the total density of points. Although this area shows a high-intensity value, in contrast, it designates the low emissivity value which is around 0.1 - 0.2. It means that this surface only emits one or two tenth the amount of energy of a blackbody at the same temperature.

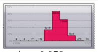
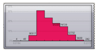
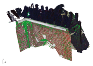
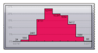
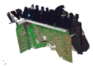
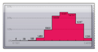
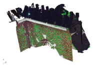
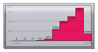
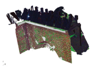
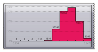
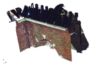
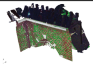
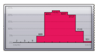
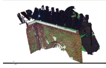
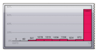
Second, we calculated the albedo values according to the available RGB colour information contained in the dataset. By searching the average values of each point and then dividing it into 255 colour unit, we can list each albedo attached to each point data. Figure 6 illustrates further a classification of the dataset based on the albedo values. It is coupled with

Figure 5
Surface distribution of the dataset according to intensity and emissivity values

| INTENSITY | DATASET | SELECTED AEAS | SELECTED POINTS ⟶ | EMISSIVITY |
|---|---|---|---|---|
| 0.0 - 0.1 |  |  | 74.047 ( 5.6 % ) | 0.9 - 1.0 |
| 0.1 - 0.2 |  |  | 537.490 ( 40.7 % ) | 0.8 - 0.9 |
| 0.2 - 0.3 |  |  | 46.097 ( 3.5 % ) | 0.7 - 0.8 |
| 0.3 - 0.4 |  |  | 65.995 ( 5 % ) | 0.6 - 0.7 |
| 0.4 - 0.5 |  |  | 172.318 ( 13 % ) | 0.5 - 0.6 |
| 0.5 - 0.6 |  |  | 302.742 ( 23 % ) | 0.4 - 0.5 |
| 0.6 - 0.7 |  |  | 68.313 ( 5.2 % ) | 0.3 - 0.4 |
| 0.7 - 0.8 |  |  | 17.706 ( 1.3 % ) | 0.2 - 0.3 |
| 0.8 - 0.9 |  |  | 8.818 ( 0.7 % ) | 0.1 - 0.2 |
| 0.9 - 1.0 |  |  | 25.670 ( 2 % ) | 0.0 - 0.1 |

*Total density of point = 1.319.196 (100%)

the calculation of total albedo and reflectance values corresponding to the percentages of the covered areas. The total (Δ) albedo allows us detecting the possibilities of albedo modification in certain areas related to the selected properties. For example, we can modify or substitute certain areas of the pavement by placing trees in order to reduce the temperature of the surfaces. This then can be useful to reduce the global heat island effect by focusing the increment albedo on the selected urban elements.

| SURFACE | ALBEDO | TOTAL AREAS (%) | TOTAL Δ ALBEDO | REFLECTANCE |
|---|---|---|---|---|
|  | 0.1 | 5.7 % | 0.0057 |  Av = 0.078 |
|  | 0.2 | 40.3 % | 0.0806 |  Av = 0.119 |
|  | 0.3 | 3.9 % | 0.0117 |  Av = 0.214 |
|  | 0.4 | 4.7 % | 0.0188 |  Av = 0.339 |
|  | 0.5 | 11.2 % | 0.056 |  Av = 0.466 |
|  | 0.6 | 22.5 % | 0.135 |  Av = 0.565 |
|  | 0.7 | 7.6 % | 0.0532 |  Av = 0.643 |
|  | 0.8 | 1.4 % | 0.0112 |  Av = 0.752 |
|  | 0.9 | 0.7 % | 0.0063 |  Av = 0.849 |
|  | 1.0 | 2 % | 0.02 |  Av = 0.983 |

*Total density of point = 1.319.196 (100%)

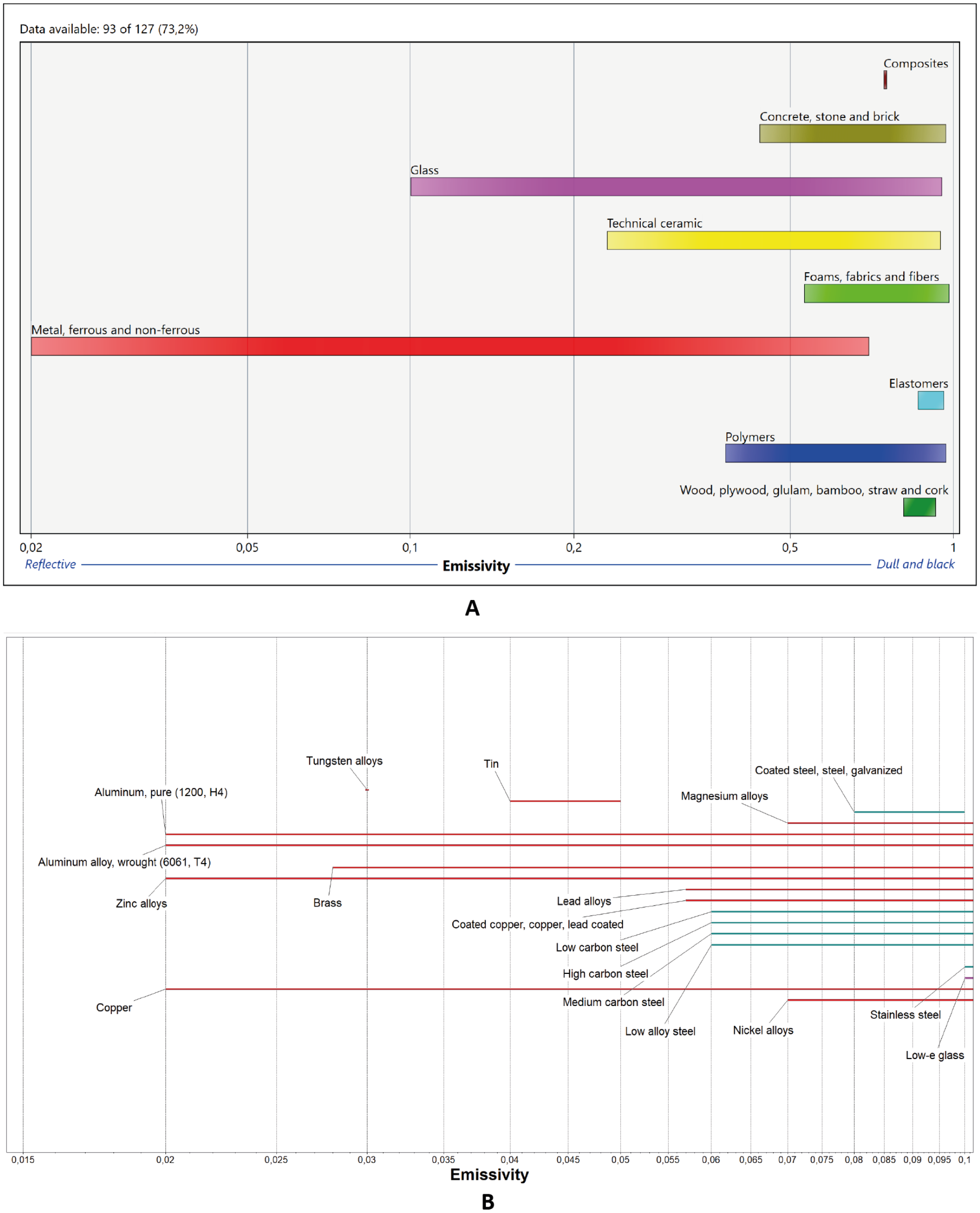
Figure 6
Surface distribution of the dataset according to the albedo and reflectance values

The inclusion of reflectance (solar reflectivity) shown in the graphics (see Fig.6) demonstrates the characteristics of the surface dataset in determining the material types. For the conceptual clarity, yet the calculation of reflectance values accounts the opaque material properties according to the portion of given available dataset. The reflectance ranges indicate the similar pattern to the albedo values. The albedo range 0.1 corresponds to the average reflectance values of 0.078 which represent the smallest values. On the other hand, it designates that the black surface on the dataset corresponds to the small reflectance values. The Figure 6 also illustrates that the albedo values 0.2 represent the largest portion of dataset indicating around 40 % of the total dataset. This number simultaneously refers to the low range of reflectance values, 0.119.

Third, identification of the material according to its emissivity values. This process is conducted by exploring the architecture materials contained in CES EduPack 2017. Having set the selection stage through the chart media, we can filter the list of materials that meet the required criteria. As illustrated in Figure 7 A, only 93 of 127 materials are available for the emissivity results. This result is then only consisted of 9 type of materials starting from the most reflective materials up to the dull and black surface: metal, ferrous and non-ferrous (0.02 - 0.7), glass (0.1 - 0.95), technical ceramics (0.23 - 0.95), polymers (0.38 - 0.97), concrete, stone and brick (0.44 - 0.97), foam, fabrics and fibers (0.53 - 0.98), wood, plywood, glulam, bamboo, straw and cork (0.81 - 0.93) and elastromers (0.86 - 0.96).

Furthermore, Figure 7B illustrates the specific sample of materials from the emissivity range between 0.0 - 0.1 which is also included in the category of metal, ferrous and non-ferrous. There are at least 17 materials identified in this range. To the following emissivity range, the same selection mechanism can be performed. In general, these identified materials correspond to the values extracted from the dataset. It provides us variety of options related materials contained in a certain surface dataset. For architects, the material properties of the existing environment are used to identify the proposed materials in the new building design. It allows architects considering the material selection during a design decision phase.

Figure 7
The material selection based on the emissivity values



## CONCLUDING REMARKS

This study investigates the attributes of point cloud data contained in the raw dataset for identifying the material characteristics in the existing environment. It specifically addresses the use of intensity and RGB colour information to determine the emissivity, albedo, and the reflectance values. The thermal and optical properties drive further into the series of analysis of the surface dataset that can be applied in the larger urban context. In so doing, architects can calculate and predict the material performance of the existing environment that can affect their conceptual design. The ultimate aim is to maintain the quality of the built environment between the existing context and the proposed design.

There are, however, some limitation that should be considered further such as calculation of the reflectance values that only relies on the opaque material properties due to the dataset availability, the material selection (shown in Fig.7) should account not only from the emissivity parameter but the albedo and the reflectance values also need to be synchronized together. Thus, the material properties can yield the optimum values from the intersection of those set parameters.

For further study, it is recommended to test the proposed method into the larger scale of the urban context. Thus, we can map the material properties of the existing environment in combination with the complexity of the urban morphology and the building functions. In the future, the calculation of refractive and the transmissivity values of the material properties also needs to be addressed due to the identification of light visibility onto the surface dataset. At last, the inclusion of the proposed workflow into the environmental simulation during the conceptual design process.

## REFERENCES

Ashby, MF, Fernandez, J and Gray, A 2008, *The CES Edupack database of architecture and the built environment*, Granta Design Ltd

Feng, Q 2012, *Practical application of 3D laser scanning techniques to underground projects*, Rock Engineering Research Foundation, BeFo Report 114

Fujita, Y, Kobayashi, I, Chanseawrassamee, W and Hoshino, Y 2014, 'Application of attribute road surface point cloud data in road maintenance', *Journal of Japan Society of Civil Engineers, Ser. F3 (Civil Engineering Informatics)*, 70 (2), pp. 1185-1192

Kashani, AG, Olsen, MJ, Parrish, CE and Wilson, N 2015, 'A review of Lidar radiometric processing: from Ad Hoc intensity correction to rigorous radiometric calibration', *Sensors*, 15, pp. 28099-28128

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*, 67(2), pp. 95-102

Shih, NJ 2012 'The application of a 3D scanner in the representation of building construction site', *The 19th International Symposium on Automation and Robotics in Construction (ISARSC)*, Washington

Weinmann, M 2016, *Reconstruction and analysis of 3D scenes*, Springer International Publishing

White, DA 2013, 'Lidar, point clouds, and their archaeological application', in Comer, D.C. and Harrower, M.J. (eds) 2013, *Mapping archaelogical landscape from space*, Springer Science+Business Media, pp. 175-186

[1] http://desktop.arcgis.com/en/arcmap/10.3/manage-data/las-dataset/what-is-intensity-data-.htm