Aged Shape Deterioration Visualization Based upon 3D Shape Measurement - Observing Brick Wall in Ayutthaya Relic -

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Abstract

It is important for the consevators/curators to verificate and quantitatively evaluate their treatment effectiveness of certain cultural property in order to prevent their acts from giving it the bad effects. However, they couldn't investigate their effectiveness in detail so far. This paper proposes the method to evaluate that quantatively by visualizing its shape deterioration process through its 3D shape data obtained by the laser range sensor. The target assets for our study is the brick wall in at the Mahathat temple in the Ayutthaya ruin in Thailand which was drastically decaying and so a countermeasure was carried out recently. The 3D shape data was captured three times before and after the treatment. This paper also provides the effectiveness evaluation of its treatment together with its evaluation method.

1 Introduction

It is important for the experts concerning the conservation and preservation of certain cultural property to verificate and quantitatively evaluate the effectiveness of their treatment because, in the past, there were some cases where their acts provide no effectiveness, or result in the worse preservation condition of the target assets so far. Their evaluation of the effectiveness is usually subjective because they are almost their impression they have when observing the treated assets.

Kuchitsu and Hayakawa[1] are tackling with the quantitative evaluation in their concervation research. Their aim is to treat the brick wall which is being decaying in progress due to the weathering, by using a synthetic resin. Before and after their treatment, they measured the amount of the decaying pieces for a year, and regarded the amount difference as the effectiveness of their treatment.

However, in their evaluation, we can figure out only the total amount of decaying pieces from the whole wall: it is not that we grasp the deterioration detail; namely, which part of the wall and how much is decaying. To verify the concrete effectiveness of their treatment, the evaluation method which enables the indication of the decaying presense and part is required.

Today, the 3D shape restoration of the real object have made progress with so little measurement error. If the treated area of the target is captured twice at the different time by using this technique, its effectiveness is represented by the shape change: more decaying cause more change of the shape. We have already constructed the observation system of the shape change through 3D measurement data for the investigation of the excavated ancient bronze mirrors[2]. In this paper, we applied this method to the conservation evaluation.

We chose the brick wall at the Wat Mahathat of Ayutthaya Site in Thailand as a target for this study. The brick wall was drastically decaying[3], so their treatment was taken[4]. We measured the 3D shape of the treated area twice and once before and after the treatment respectively, and evaluated the treatment effectiveness based on the 3D data (Figure 1).

This paper is organized as the following. First, we describe the 3D shape reconstruction of the real object in the computer graphics. Then we explain the evaluation methodology, the experimental result, and the consideration about it. Finally we conclude this paper, including our future work.

Figure 1: Measurement in Dec. 2003.

2 Acquisition and Registration of 3D Shape Data

The target area of the wall was measured by using the VIVID 900 manufactured by KonicaMinolta Inc. The VIVID 900 is a triangulation type laser range sensor that can measure the distance by calculating the difference of the position at which the laser ray, emitted from the sensor as a slit light and reflected against the object to the sensor, is observed in the CCD. It has three kinds of lens, and we then used the lens which covers the narrowest area but enables the most accurate measurement. The data set of the target area were obtained three times: March, 2001, Decemeber, 2003, and September, 2004. (We plan to measure the same area in December, 2004.)

The laser range sensors cannot measure the whole target in one measurement because of their range limitation. To resolve it, multiple measurement is applied, which, as a consequence, requires the registration of the data (Figure 2) for the whole target shape restoration. In the 3D data registration, the Iterative Closest Point (ICP) [5] is commonly used. The conventional registration method based on ICP is a sequential technique which handles only one pair of data per one registration[6]. If the number of data consisting of the whole shape is small, the accumulation error of the registration can be ignored; however, if the number is large, the registration of the whole shape tends to fail. Oishi et. al. developed the registration method, which can evenly distribute the accumulation error by registering all data simultaneously [7]. This method produces more accurate shape restoration than the sequential one. As a matching unit of our registration, the distance between the point and the plane is used in order to increase the accuracy of the registration. In Addition, to reduce the outlier effect, our method uses a thresholding for the correspondence, by considering the distance between the corresponding points and the measurement error. The search for the corresponding point is usually expensive computationally, yet our method can reduce the computational cost drastically, since its search computation mainly depends on the graphics hardware.

3 Comparison and Visualization Methodology

Now we obtain the whole shape data of the target area. Next, we have to globaly register the data set of the different year or season because their differences appears localy. The global registration is achieved in the same way as the above

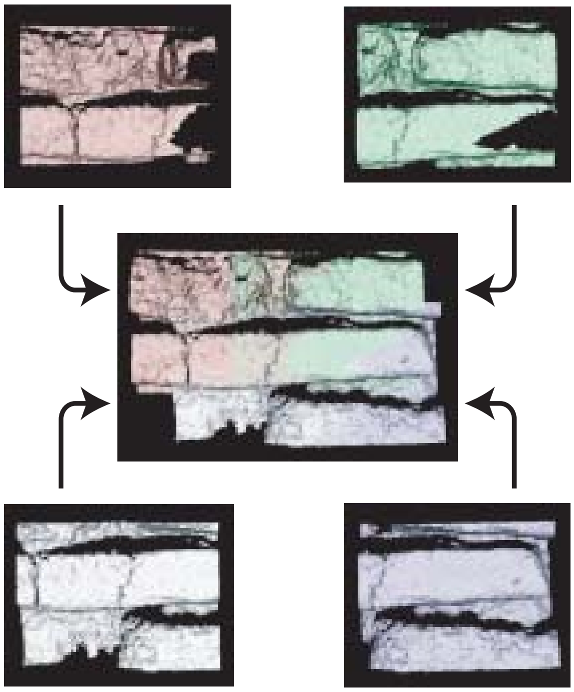

Figure 2: Registration. Registration can restore the relative position and posture between each corresponding pair of range images as shown in the lower illustration.

alignment method by regarding one data set as the registered piece for the comparison.

Finally, we need to calculate the difference of the compared data set. Here we define the difference as the signed distance of the nearest neighbor. Namely, the difference is determined by the signed distance field which the other (compared) data set composes.

Figure 3 illustrates the calculation of shape difference. The target and compared data of the wall are respectively shown in Figure 3 as the solid and dotted line. A point in the target data has its nearest neighbor on the compared data as its corresponding point. The shape difference is represented in mathematical form as:

$$d = sign(\overrightarrow{n(v)} \cdot \overrightarrow{vv_c}) \times |\overrightarrow{vv_c}|,$$

$$\begin{array}{lll} where & v & \text{point on target data,} \\ & \overrightarrow{n(v)} & \text{normal vector of } v, \\ & v_c & \text{corresponding point of } v. \end{array}$$

and

$$sign(a) = \begin{cases} -1 & if \quad a < 0 \\ 1 & if \quad a \geq 0 \end{cases}$$

d is calculated on all points in the target data. The normal vector for each point is defined as the normalized vector of the sum of the normal vector of the plane where the point is the member. This value allows us to recognize their relative convex or concave shape difference to the compared data. Positive d indicates that the target area is more convex; otherwise it is more concave.

4 Experiment and Consideration

In this experiment, we used three data set of the observation area on the wall. The first, second, and third data set consists of 23, 341, and 411 pieces of the measurement data, respectively. The measurement error is less than 0.008[mm].

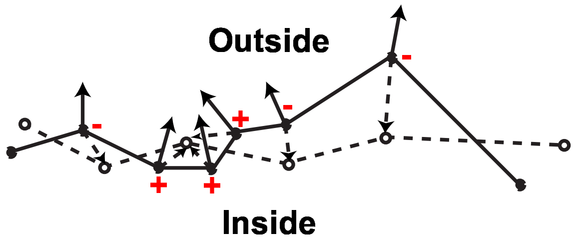

Figure 3: Example of signed distance calculation

Figure 4 and 5 are the visualization results of the decaying. The red and blue area represents the convex and concave difference which is more than the setting threshold respectively, while the green area is regarded as no difference because its difference is within the setting threshold.

Judging from the picture taken before the first measurement and this result, the concave difference areas are decaying drastically, and we can observe it through the captured 3D data. In the future, more measurement leads to the understanding of the detail decaying process.

5 Conclusion and Future Work

In this paper, we applied the observation system of the shape change through 3D data to the decaying process observation of the brick wall in Ayutthaya Relic in order for the conservators/curators to quantatively evaluate the effectiveness of their treatment. As a preparation of the observation, we described the 3D shape acquisition and registration briefly, and presented the evaluation methodology. Using our observation system, we could observe what part and how much is decaying.

We plan to measure the same area in December, 2004, and continue to observe the decaying process for the conservation purpose.

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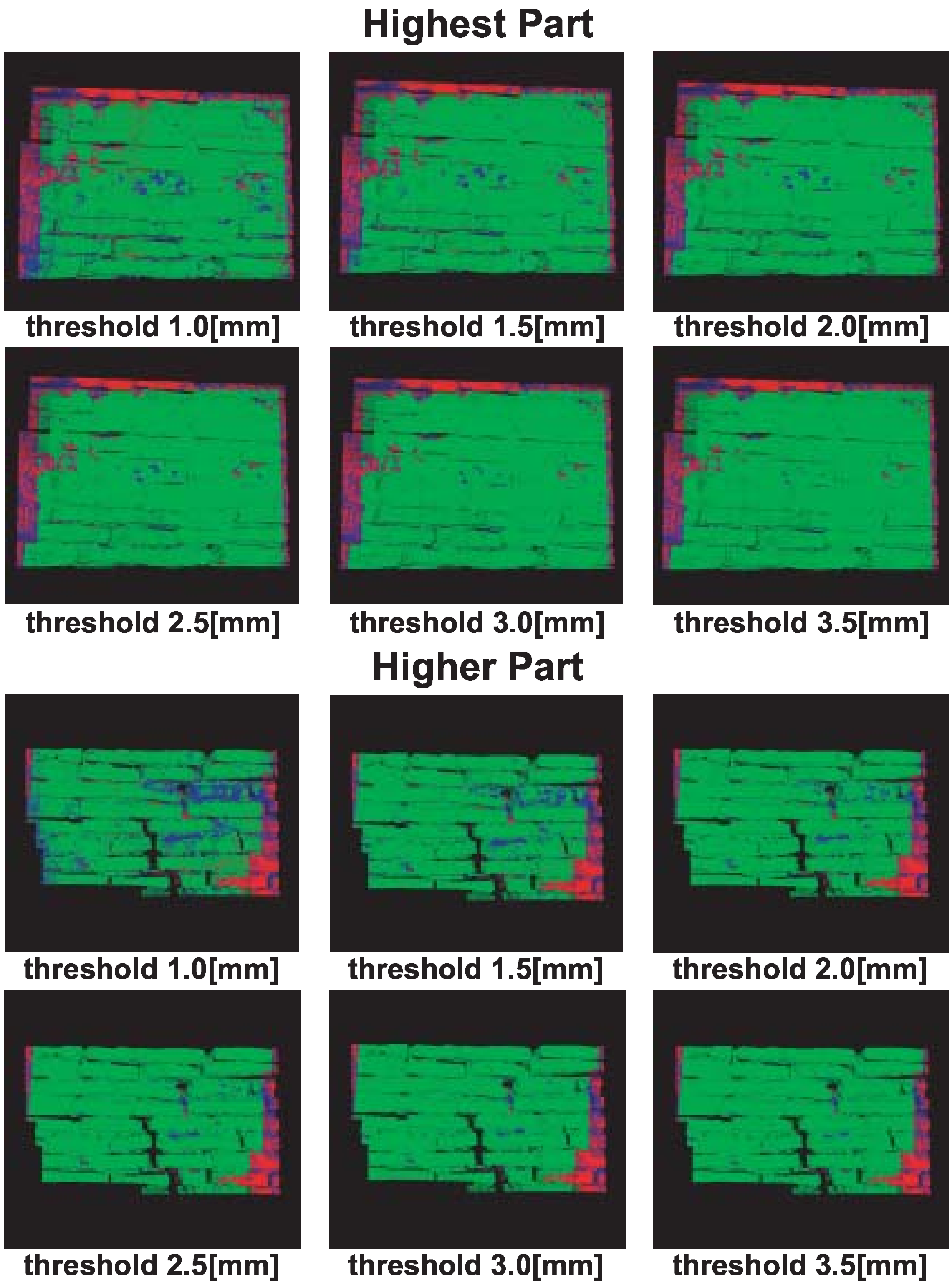

Figure 4: Result of the highest and the higher area.

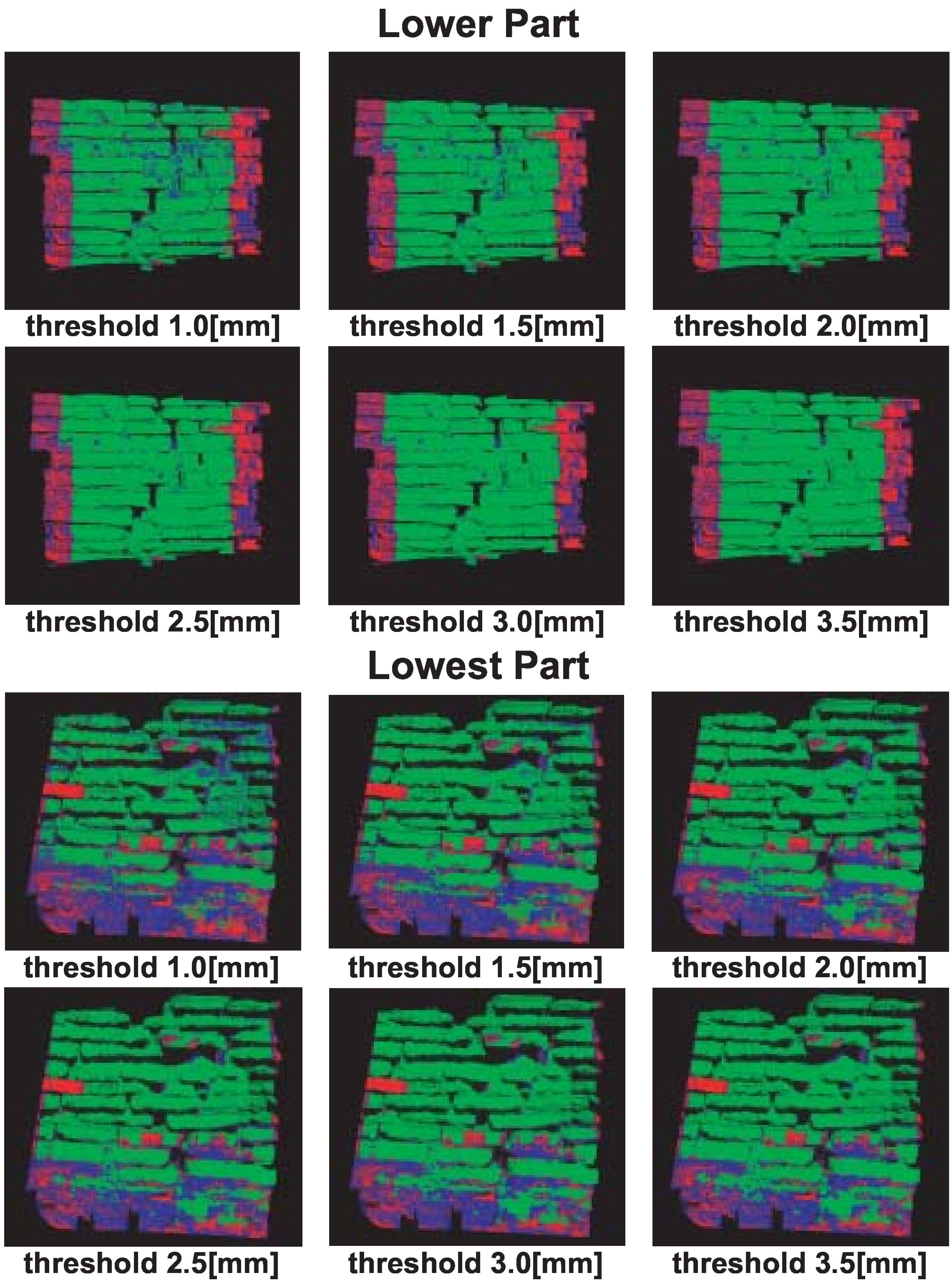

Figure 5: Result of the lower and the lowest area.