Visualizing a Scanned Model for Effective Heritage Interpretation

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***Abstract*— Scientific analysis of the scanned model can enhance interpretation of heritage. Visualization methods that use various rendering algorithm can reveal geometric features of the model clearly, which may not be recognized in pictures or even on the site. Thus it helps to overcome the subjectivity or restriction in first-hand interpretation. In this paper, visualization of scanned model for interpretation of heritage was surveyed. Based on that survey, a classification scheme was proposed which can be used in the interpretation pipeline. In a case study of dinosaur track, we analyzed the possible problems in the interpretation stage and proposed various visualization of scanned model according to the purpose. User test was performed to evaluate the effectiveness of the method. A practical survey in this paper showed that 3D scanned model and its appropriate visualization could be used for effective interpretation of heritage.**

Keywords—3D scan; heritage interpretation; rendering; visualization

I. Introduction

The 3D scanning technology enables effective scientific analysis, representation, and interpretation of cultural and natural heritage. However, currently it is difficult to expand its application because only technically skilled experts can handle the scan data deftly, and also because there are few specific software development taking place in the domain [1]. Images that effectively visualize the geometric characteristics of scanned data are useful to heritage experts as support a more objective and novel interpretation of perspectives. In this paper, we analyzed several rendering methodologies appropriate for visualizing such 3D scanning models and presented a method allowing for effective interpretation by applying them.

II. Related Work

A. 3D Scan of Cultural and Natural Heritages

3D scanning projects are being performed in a wide range of areas including artifacts, historic sites, and excavation sites led by governments and research institutions of many nations [2-5]. Scanning is mainly used for 3D recording, reconstruction, and monitoring. Recently, several different methods have been combined [4,6]. The 3D scanning of natural artifacts have a relatively lower rate of utilization as of yet [7-10].

B. Visualization of 3D Model through Rendering

Photorealistic Rendering allows intuitive recognition, while Non-Photorealistic Rendering can highlight specific geometric features. Among the Non-Photorealistic Rendering techniques to implement line drawings, there are ridges and valleys [11], suggestive contours [12], apparent ridges [13], demarcating curves [14], and laplacian lines [15] methods, etc. Among the methods to clearly express the bumps on the surface or the outlines of the objects are the accessibility shading [16] and ambient occlusion [17] methods that entail expressing the shades depending on the accessibility of each point on the surface. Also, there are the exaggerated shading [18] and the light warping [19] method.

III. Visualization of 3D Scan Data

A. First Level Interpretation

Fitch argued that there are the 'professional' and 'popular' levels in interpretations based on heritage information [20]. Professional research and record possible evidences to provide information for interpretation at the popular level. First-hand experiences are limited at such second levels. The role of first level interpretation grows even more when it is difficult to physically access the sites or the artifacts. Especially, if there are additional interpretations by peer professionals based on the results of first impression, the objectivity and accuracy become further important. The Fitch Model in this instance can be further categorized as follows:

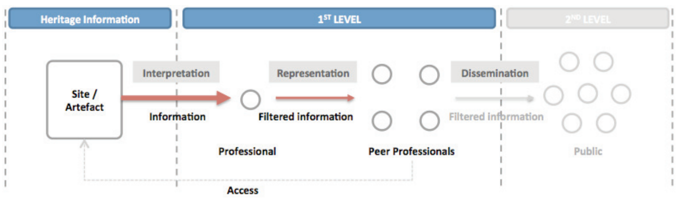


Fig. 1. Modified interpretation model

The scan model used in the interpretation by shape analysis can strengthen the first level analysis through the analysis and visualization, while also replacing the accessibility to the site through sharing and distribution of data. The process is illustrated in Fig. 2.

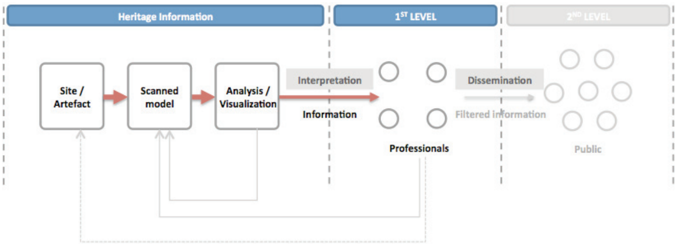


Fig. 2. Interpretation model with scanned model used

B. Classification of Rendering Techniques for Visualization of 3D Models

We divided the rendering techniques into *reality-based* and *feature-based* according to their expressive characteristics. They can also be classified as *global shape* and *local shape* depending on whether the overall volume of the 3D shape or the local characteristic is mainly expressed. We built the classification scheme for visualization of 3D model, which has two axes (Fig. 3). The rendering techniques included in related work have been placed on the classification scheme.

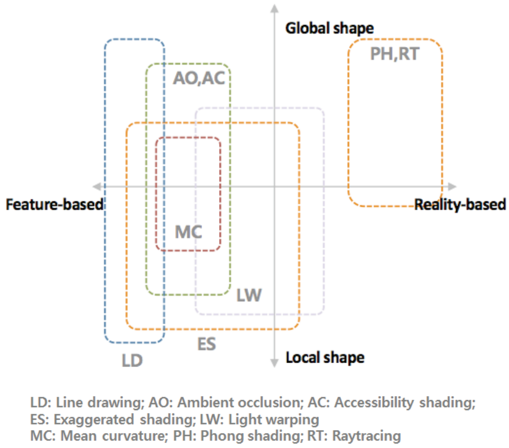


Fig. 3. Categorization of rending techniques

IV. Case Study of 3D Scanning Visualization - Dinosaur Track

A. Problems in Traditional Research Process

Paleontologists first visually recognize the shape of dinosaur track on the site. In general, the fossils are directly drawn on transparent films or recorded by taking photos of them, or cast by silicon, and measured by hand. With regards to each stage of the process of verifying and interpreting the dinosaur footprints, the following problems have been noted related to visual recognition.

1) Visual ambiguity: The human sight has the tendancy to assume one source of light originating from the above when perceiving images (Light-from-above) [21], so if the source of light is from below or if the light dissipates, it can result in visual ambiguity. The shape of footprint may appear different depending on the location of the light source (Fig. 4).

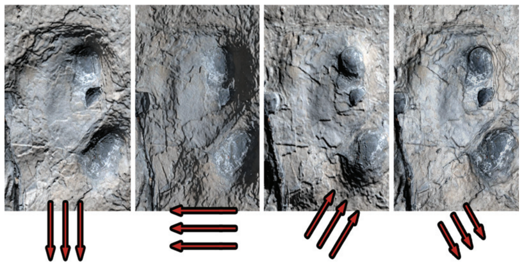


Fig. 4. Footprint appearing different depending on the light source

2) Difficulty of recognition by color: Complex color makes it difficult to recognize the shape or relative depth.

3) Inaccurate measurement: The level of accuracy is low following subjective measurement standards and inaccurate depth measurement at the reference surface.

4) Distortion during the Recording Phase: When taking photos, there are difficulties to avoid the distortion.

5) Information loss: Drawings can often lose significant information such as 3D infomration and detailed shapes due to excessive simplification.

6) Difficulty of recording: The cast used to extract 3D information may damage the fossils, and are limited in distribution or sharing.

7) Bas-relief ambiguity: When objects with Lambertian relection are seen vertically, it can result in ambiguity in recognizing 3D shapes. There are also instances when the shape of the model changed in specific methods have identifcal structural image as the original [22]. In Fig. 5, while the internal shape of the footprint can be different, the image (right) can seem almost identical. This presents the possibility of ambiguity occurring upon photo recording or 3D rendering.

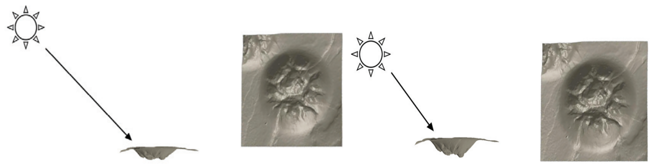


Fig. 5. Bas-relief ambiguity

8) Subjective interpretation: Determining detailed shapes of the footprint or measurement criteria from dinosaur track depends on subjective interpretations or judgments. Thulborn had pointed out earlier about such difficulties as well as the issue of subjectivitiy following them [23].

B. Results of Visualization

With the objective to visualize 3D scanned models of dinosaur footprints, we've set 4 visualization goals which are: (1) objective expression, (2) recording of the status, (3) visualization of depth information, and (4) basis on interpretative drawing. Each plan can be located on the classification scheme as Figure 6.

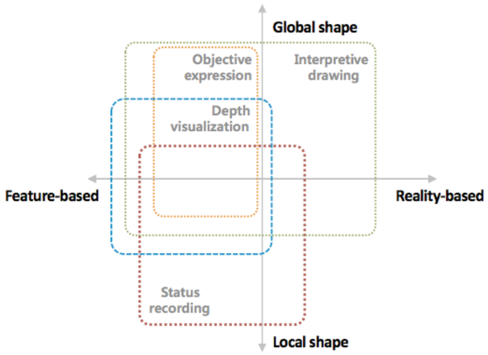


Fig. 6. Classification of visualization plans depending on the objective

1) Objective Expression : By visualizing the footprints in an objective way, recognition and interpretation becomes objective and clear. To this end, ambient occlusion can be applied, which utilzes the shape regardless of the light source.

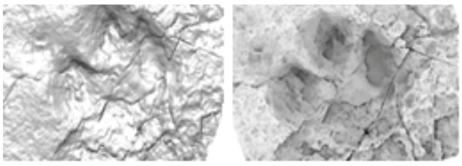


Fig. 7. Phong shading (left) and ambient occlusion (right)

2) Recording the Status: The non-photorealistic rendering such as exaggerated shading, mean curvature, or light warping can emphasize shallow or small cracks of the site (Fig. 8).

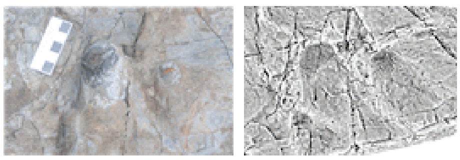


Fig. 8. Visualization of fossil cracks

3) Visualization of the Depth Information: The depth information is critical for analysis of locomotion of dinosaurs. The contour lines or color ramp images can be generated from the 3D model to display the distribution of depth.

4) Basis of Interpretive Drawing: In the image to be provided as the background for the drawings, the overall shape and local detail shapes must both be shown clearly to allow accurate recognition and interpretation of the footprints. As the ambient occulusion expresses shapes objectively, it has the strength as the basis of the drawing. However, as the strength of the darkness is unrelated to depth, it is different from the dark-means-deep model [24] which tends to perceive the darker parts to be deeper in general.

5) Expression of Multiple Resolutions: In case of tracks, the precise location and shape of footprints need to be shown at the same time. For the purpose, a multi-resolution model, which combines a long-range scan data with precise scan data, can be built and visualized by rendering.

V. Experiment

We've subjected active experts who work in the field of dinosaur footprint research to survey the issues in the interpretation as well as a drawing experiment.

A. Test I

We tested how subjectivity or differences in perspectives affected the interpretative results when drawings are performed in the actual dinosaur footprints. Three experts participated. The FL (Foot Length), FW (Foot Width), Pace, and Stride values were measured for the identical tracks.

B. Test II

We've performed a drawing test to four experts to see whether using the visualization image as the basis of drawing is more effective than drawing on the site, and helps with shape recognition as well as securing objectivity. Transparent films were assigned on footprint images- photos, phong shading, and ambient occlusion images for three footprints.

VI. Results and Discussion

A. Test I

Measurement results of 3 experiment subjects are shown in Table I. On the first row are participants' numbers.

TABLE I. Measurement Results

No	Measurement Values (cm)								
	FL_1	FW_1	FL_2	FW_2	FL_3	FW_3	$P_{1\text{-}2}$	$P_{2\text{-}3}$	SL
1	38.0	40.0	39.0	38.0	**38.0**	**40.0**	78.0	87.0	154.0
2	32.0	34.0	33.8	32.0	**30.0**	**32.0**	75.0	85.0	153.0
3	38.5	37.3	34.2	35.5	35.3	34.8	75.2	84.4	154.2

[a] FL: Foot Length, FW: Foot Width, P: Pace, SL: Stride Length; Subscript is footprint's number

The sizes and speeds of dinosaurs as determined from the measurement results are shown in Table II below.

TABLE II. Caculated Resuts from the Measurement

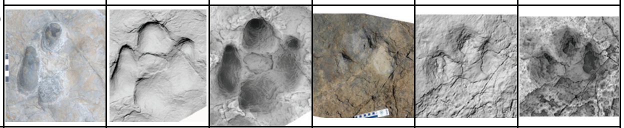
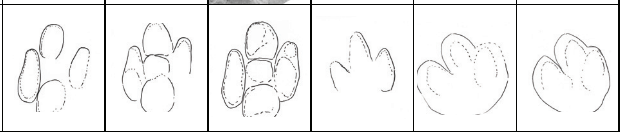
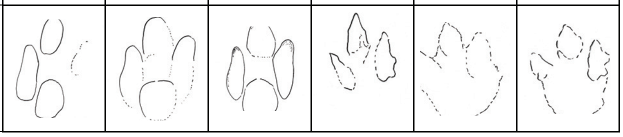
No	Hip height h(m)	SL/h	Speed (km/h)		
			Alexander's	Thulborn's	Mean
1	2.2597	0.68	2.23	4.9	**3.6**
2	1.8821	0.81	2.74	5.58	**4.16**
3	2.124	0.73	2.41	5.15	**3.78**

Mean value of three FL was used to calculate hip height. The relative stride length (SL/h) is used to determine whether the animal is walking (SL/h<= 2.0), trotting (SL/h>2.0 and <2.9) or running (SL/h>=2.9). As for the speed of dinosaur, Alexander's formula and Thulborn's formula was utilized, and mean value was derived from the result. As seen in the above results, the calculated results are different according to the measurement value of each participant. The differences at first level interpretation on site can supply inaccurate data to peer researchers performing subsequent studies based on these.

B. Test II

Two results among the results of drawing test were selected and included in table III.

TABLE III. DRAWING RESULTS OF TEST II

No	Results					
	T1			T2		
	Photo	PH	AO	Photo	PH	AO
						
P1						
P2						

[a] T: Test, P: Participant, PH: Phong shading, AO: Ambient occlusion

While the outline was drawn using the information provided by internal color on photos, the shades in accordance with changes in shapes were used for the drawing in rendering. We confirmed that the rendering images – especially the non-photorealistic rendering images – allowed clear recognition of the shape and expression of detailed shapes. In the survey performed after the drawing, all answers showed that the photos were the least effective, and most answers showed that the non-photorealistic rendering images were the most effective and the renderings were better than direct drawing. As can be seen in the results, the non-photorealistic rendering images rather than the photos allowed easier recognition of the shapes and provided further detailed drawings. This indicates that the effective visualization fitting the purposes affected the interpretation of the actual experts positively.

VII. CONCLUSION

In this study, we've demonstrated that appropriate visualization of 3D scanned model depending on the objective and characteristics of research in cultural and natural heritage domain can effectively support the first level interpretation by the experts in the applicable fields. To this end, we've proposed a system to classify the rendering techniques for 3D model visualization in accordance with expression characteristics, analyzed various rendering techniques, and organized the visualization plans considering the purpose of usage. In the case study applying this to the dinosaur footprints, we've analyzed the problems in traditional research and selected the appropriate rendering technique to perform visualization. Based on experiments performed subjecting experts using these results, we've confirmed that the analysis and results from this study were correct. As discussed in this study, the 3D scan data and its visualization techniques can function as a strong foundation for effective interpretation of heritages, and can impart richer and more objective interpretative information for next level interpretations when utilized accordingly.

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