

Computer Rubbings with Three-Dimensional Measurement Data

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Abstract

So far we have developed high-definition 3-dimensional digital scanner for archaeological properties including relics and remains. By using our digital scanning system, combined with computer graphics technology, we have achieved digital archive system for archaeology. However, the conventional (photo-reality oriented) computer graphics technologies are not intended to visualize archaeologically-interested properties such as relieves of Dotaku (bronze bell found in China, Korea and Japan).

Archaeologists used to investigate and also preserve the relief patterns of Dotaku by ink rubbing. The authors propose a modern ink rubbing system based on our 3-dimensional [or 3-D] digital scanner and computer-based geometry processing. This "Virtual Ink Rubbing" allows us to see very minute pattern of surface of Dotaku and to directly compare existing ink rubbings of Dotakus with newly excavated relics without any danger to soil the relics by actual ink.

1. Introduction

So far we have developed high-definition non-contacting 3-dimensional digital scanner for archaeological properties including relics and remains. Fig. 1 shows our 3-dimensional digital scanner, which is equipped with Minolta Vivid 900 laser rangefinder and Polhemus motion tracker. Fig. 2 shows a computer graphics model of "digital" bronze bell scanned by our 3-dimensional scanner: We have been able to model such relics with accuracy of 0.2[mm].

Archaeologists, however, prefer ink rubbing when they investigate kinds of bronze bells since relief on the surface of the bronze bell is one of the very important properties of them. Ink rubbing is a very simple but effective method to visualize such minute pattern on the surface of relics. Though its simplicity, there is also danger to soil such bronze bells while making ink rubbing by carbon ink (Sumi).

A "Virtual Ink Rubbing" is a computer-generated ink rubbing image which is

generated by our recent extension of 3-dimensional relic scanning system. Our virtual ink rubbing system simulates actual ink and paper wrapping around a bronze bell so that we are able to have virtually real ink rubbing without soiling, or even contacting, such bronze bells.



Figure 1: Digitally scanned bronze bell in conventional computer graphics

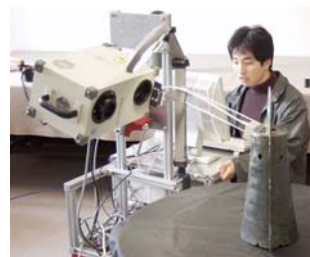


Figure 2: High-definition 3D measurement system

2. Virtual Ink Rubbing System

The overview of "Virtual Ink Rubbing" system is shown in Fig. 3.

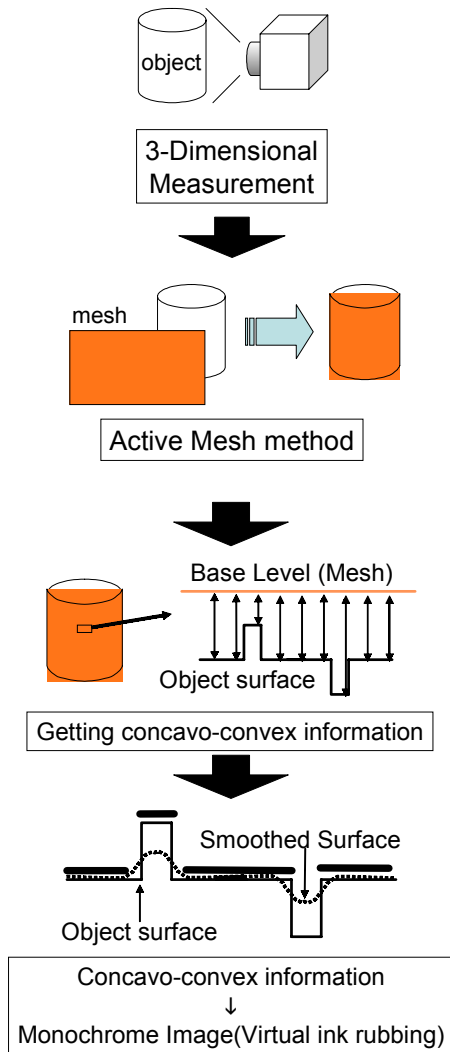


Figure 3: The overview of Virtual ink rubbing method

First, an object (relic) is digitized by our high-definition non-contacting three-dimensional scanning system. Our system is equipped with laser rangefinder (laser triangulation) which is able to scan objects with about 0.2[mm] accuracy, combined with magnetic motion tracking system. Once the 3-D shape of the object is

captured onto a computer, view registration and integration are performed on separately scanned data of the same object. Fully integrated 3-D data of the object is automatically obtained by our system.

Second, a virtual paper (a computational paper model) is simulated to wrap the scanned object by using active mesh method. In the active mesh method, the virtual paper is deformed under physical constraints of the actual paper. The virtual paper is divided into small surface element called mesh; the position, tension, and twists of each mesh are calculated based on dynamics. We give external force to the mesh step by step so that the mesh sticks to the object.

There must exist some errors on the surface data of the scanned object, which causes wrinkle on the mesh. To avoid these errors, estimation of the errors of the model is performed using maximum-likelihood method, and then the error points are eliminated.

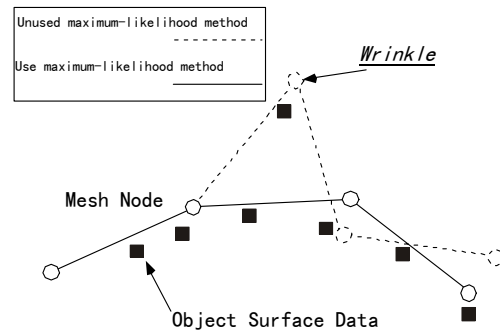


Figure 4: Error elimination in active mesh

Next, virtual ink rubbing is calculated based on the converged form of the mesh. Since the active mesh consists of polygons, to obtain a continuous surface of the mesh, bicubic spline interpolation is performed on the mesh. The distances between the mesh and the surface of the

relic are calculated on every point on the mesh. Then, the distance map on the curved mesh is stretched to planar map. The difference between the concavo-convex data and the smoothed data is computed (See Fig. 5). The smoothed data represents the curvature of paper, so the negative portion of the difference data is eliminated; ink does not adhere in concave point on the surface of an object. Finally, a monochrome image which shows virtual ink rubbing is obtained.

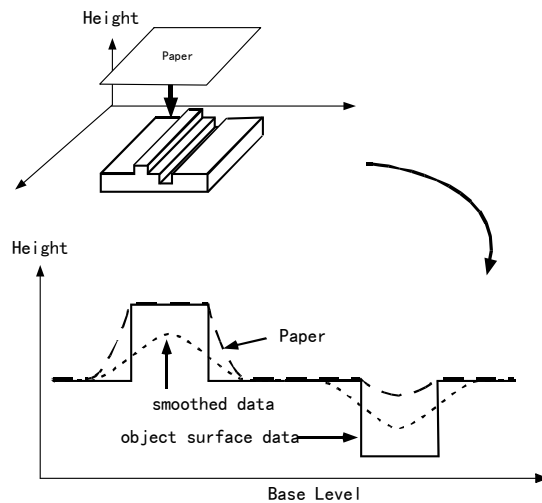


Figure 5: Conversion to monochrome image.

3. Experiments & Results

We performed the proposed method on the bronze bell (Dotaku, see Fig. 6). We made a virtual ink rubbing of a partial surface of the bronze bell.

Firstly the bronze bell was scanned by our high-definition non-contacting three-dimensional measurement system. The obtained digital model of the bronze bell in conventional computer graphics is shown in Fig. 7. The shape of the bronze bell was digitized with 0.5[mm] mesh.

Next we performed active mesh method to calculate geometry of wrapped paper around the bronze bell. To smooth the geometry, we then performed bicubic spline interpolation on

the result of the active mesh method. The result is shown in Fig. 8.

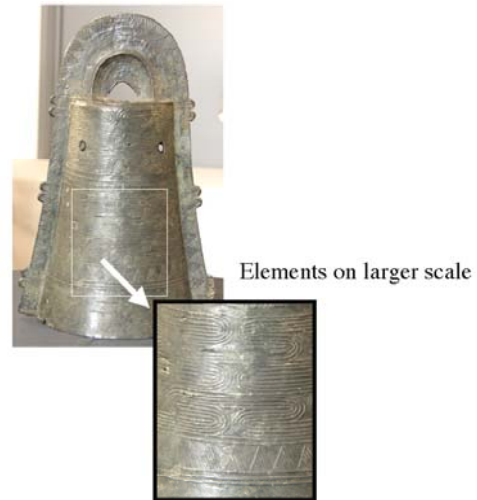


Figure 6: Dotaku (Bronze Bell)



Figure 7: 3-D model of the bronze bell

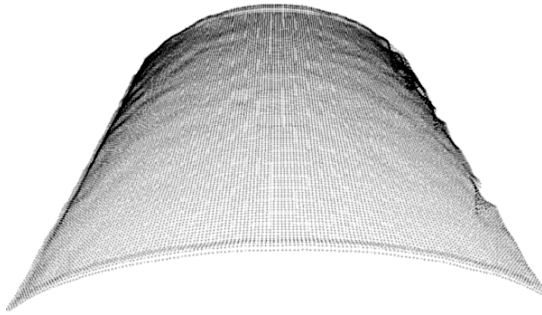


Figure 8: Result of bicubic spline interpolation

Finally we obtained the virtual ink rubbing shown in Fig. 9 by the proposed method. The actual ink rubbing on the same bronze bell taken by an expert is shown in Fig. 10 for comparison between the virtual and the actual ink rubbing.

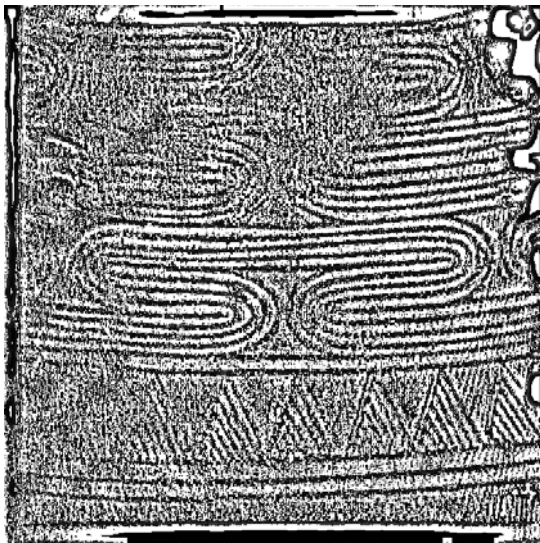


Figure 9: Ink rubbing image

4. Discussion

Fig. 9 shows that the proposed method has an ability to draw ink rubbing image very similar to the actual ink rubbing. To compare the virtual ink rubbing shown in Fig. 9 and the actual ink rubbing shown in Fig. 10, we made a "differential image" (in the inner box of Fig. 11, red means exact match between the virtual ink

rubbing and the actual ink rubbing, while white means over inking on the virtual ink rubbing) between them and showed in Fig. 11. Fig. 11 proves 1) the relief on the surface of the bronze bell can be correctly visualized by the proposed method, and 2) the spline surface created from noise-reduced active mesh well simulates wrapped paper around the bronze bell.

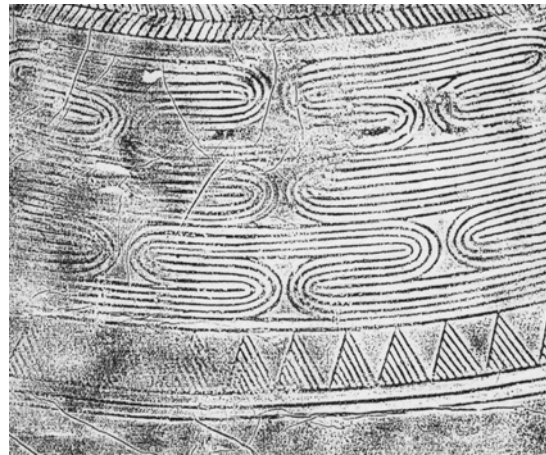


Figure 10: Actual ink rubbing



Figure 11: The comparison between the virtual ink rubbing and actual ink rubbing

The virtual ink rubbing system allows archaeologists to obtain traditional ink rubbing images while avoiding any risk to soil relics by ink and also avoiding even any danger to break the relics by touching them since our digital scanning system is completely non-contacting scanner.

Further more, our virtual ink rubbing is not depend on a skill of person who takes ink rubbing. Thus the virtual ink rubbing obtained by our proposed method certifies equal quality no matter who creates the ink rubbing.

5. Conclusion

A computer imaging of ink rubbing for culture properties with 3D shape measurement is presented. The result image shows that surface relief of object is visualized with emphasis. We apply active mesh method for simulating paper wrapping of ink rubbing. As the active mesh method has a weak point, that it needs time-consuming calculation, we are trying to use a global geometric model in order to accelerate the process for practical use.

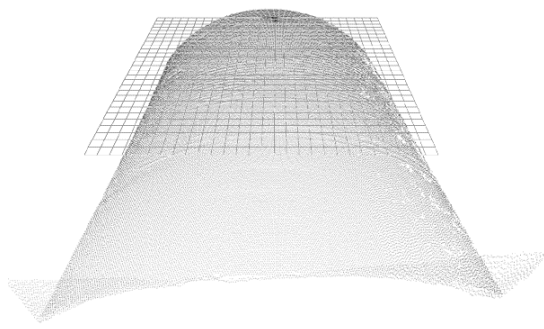
References

- [1] Tosho Norita, Sigeki Imai, and Kosuke Sato, et. al., "Prototyping of a High-Definition Digital Archiving System for Archaeological Properties", Information Processing Society of Japan, SIGCH 2001, pp.181-188, 2001. (Japanese)
- [2] Ken'ichirou Ooi, Toshio Tsukamoto, and Kosuke Sato, "Image Processing of The Three-Dimensional Measurement Data For Bronze Bell", Japan Society for Archaeological Information 13th Conference, pp.55-60, 2002. (Japanese)
- [3] Kosuke Sato and Toshio Tsukamoto, "Three-Dimensional Digital Measurement and

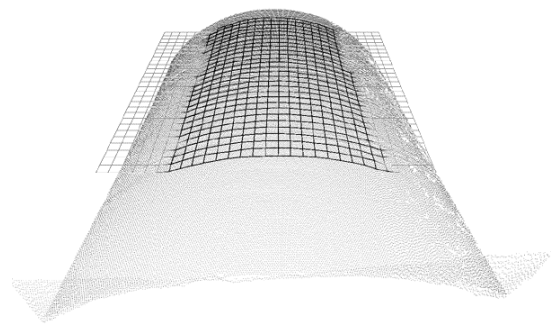
Recognition of Remains and Relics", Journal of the Institute of Electronics, information and Communication Engineers, Vol. 85, No. 3, pp. 166-170, 2001. (Japanese)

[4] F. Bernardini, J. Mittleman, H. Rushmeier, G. Taubin, J. Wasserman. "Studying sculpture with a digital model: Understanding Michelangelo's Pieta of the Cathedral.", SIGGRAPH 98 Application Sketches. Orlando, Florida, July 1998.

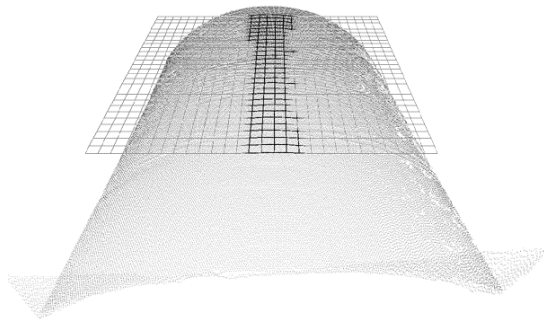
[5] Hirofumi CHIKATSU, Tetsuji ANAI, "RELICS AND VISUALIZATION IN VIRTUAL ENVIRONMENT", International Society for Photogrammetry and Remote Sensing Commission V Symposium, Hakodate, Japan, 1998,



(1)



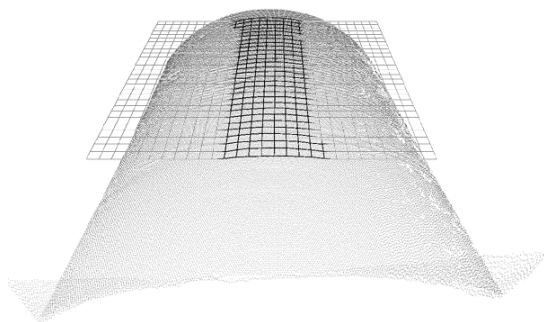
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(3)



(6)

Figure 12: Active mesh sticking to Dotaku