Title:
An Algorithm for the Detection of 3D Scanning Direction using Virtual Holes

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Introduction:
As 3D scanner and 3D printer develop, 3D related researches are being progressed in medical and other industrial fields. Amalgam is used to most restoration in dentistry field. However, amalgam has esthetic negative element because of the metallic color. Thus, esthetic materials such as ceramic usage have been increased. 3D virtual model is required for ceramic manufacture different from existing amalgam manufacture. Therefore, existing dental impression models are being scanned for converting the actual model to 3D virtual model. Generally, when 3D scanner used in dental technical laboratory is scan the dental impression as shown in Figure 1, swing and rotation angle can be adjusted to search the better scan direction. Decision of scan direction depends upon the user experience. However, they work inefficiently because most users do not have 3D related expertize. So, this paper propose that the automated detection of 3d scanning direction for dental impression model.

Fig. 1: dental impression model.

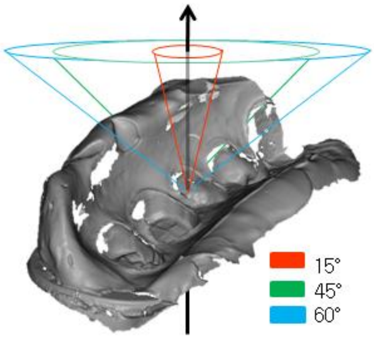

Fig. 2: Scanning with default orientations.

Related works:
To find the next proper viewing directions, it is necessary to evaluate the visibility of missing areas from images of a given range. The visibility evaluation for a given geometric model has various applications, including computer graphics, multiaxis machining, orientation of parts on a CMM (coordinate measuring machine), parting line determination for castings, and optical scanning for object reconstruction. Therefore, the visibility problem has long been studied by many researchers.

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Mehra et al. [6] presented an algorithm for estimating visibility from a given viewpoint for a point set. They computed the visibility based on a construction involving the convex hull in a dual space instead of performing an explicit surface reconstruction for the points set. Wang et al. [11] proposed an adaptive visibility sampling algorithm for the all-frequency rendering of dynamic scenes, which comprises two steps: adaptive visibility sampling and hemispherical distance transformation. Park [7] presented a procedure to compute pencil curves from a given triangular mesh model. For the computation of visible pencil curves, he used a graphics board to accelerate the computation. Kang and Suh [2] proposed a method for calculating the setup orientations for five-axis machining that is implemented by numerical simulation. Kweon and Medeiros [3] presented a method to determine part orientations on a CMM that utilizes the visibility map to represent accessible directions. Spyridi and Requicha [10] suggested an algorithm that calculates the accessibility of a CMM probe based on the concept of an accessibility cone. They divided an accessibility cone into local and global accessibility cones to determine the bound of the possible probe orientations. Singh and Madan [9] suggested a procedure to determine the parting line for die-cast parts. Their procedure applies die-casting process requirements along with geometrical reasoning to determine the parting line of the die-cast parts. Lee and Park [4] suggested a measuring procedure of parts based on a laser scanning mechanism. Their procedure uses the concept of local accessible directions (LADs) and assumes that a CAD model is available for the part; it determines the scanning directions that cover the surface of the part by performing Boolean intersection operations among LADs. Although there have been many previous results, they cannot be applied directly to the problem of scanning dental impressions. Most of them evaluate the visibility for a complete model, whether it is a CAD model or a point cloud model. Because a dental impression represents the tooth structure of a human, we cannot have a complete CAD model prior to finishing the scanning operation.

In the area of optical scanning, Scott and Roth [8] surveys and compares view planning techniques for automated 3D object reconstruction and inspection by means of active, triangulation-based range sensors. They classify existing non-model based view planning methods into three categories: 1) volumetric, 2) surface-based, and 3) global. Once again, the surface-based methods are separated into three approaches: 1) occlusion edge, 2) contour following, and 3) parametric surface representation. Among these, occlusion edge method [1, 5] is the most commonly used traditional method, and it is based on the premise that occlusion edges internal to the image indicate surface areas not yet sampled (missing areas). Maver and Bajcsy [5] selected a viewing direction by reasoning about the angular arc through which occluded areas of the object surface can be viewed, based on assumptions about the unseen topography. Garcia et al. [1] also utilized an occlusion edge method, and their method is based on a voting scheme that takes into account the orientation of occlusion edges.

Main Idea:

As shown Figure 2, we scan from fifteen default directions for obtaining a broad outline before applying the algorithm. Patches are provided from each direction in real time, and does not merge with each other. The merge algorithm is not available in real time because of excessive performance time. Thus, patches obtained are not one single tri-mesh, and the holes that consist of different patches are unable to be detected. In this paper, the hole that consists of different patches is called 'virtual hole'. To detect scanning direction, it is necessary to go through three important steps: (1) definition of the scanning area; and (2) detection of the contact surface and creation of the virtual hole; (3) filtering the virtual hole and consideration of global interference; (4) creation of normal vector using fitting plane.

In the first step, we define the scanning area. Teeth shape lies inside the model due to the characteristics of the dental impression model. So, the outside of model no need to scan. For this reason, we project 3d model onto 2d plane. And we create boundary polygon using the distance from center of model. This boundary polygon converts into a 3d space and is shown in any direction because of ignorance of depth. The consequence is that the teeth shape is located in the boundary polygon in any direction.

The second step is an algorithm to detect the contact surface within patches in order to do like a single tri-mesh. To real time application, contact detection is calculated using distance between points instead of collision detection between triangles. Each voxel is computed at the same time using GPU parallel computing after splitting uniform grid space. Therefore, contact detection is possible in real time.

In the third step, we detect boundary triangles instead of triangles including contacted points. The virtual hole is created by grouping boundary triangles using distance of boundary triangles. Virtual holes of the outside of a boundary polygon are not selected.

In the fourth step, a normal vector that is standard of scan direction is created. We create a fitting plane to points of virtual hole. We check visibility of virtual hole from the 200th direction with plane normal vector as the center. In this time, the global interference is considered and the most visible virtual hole is selected.

Conclusions:

In this paper, the proposed algorithm detects the better scan direction than the direction that is decided by user. But it didn't find all reasonable direction. Nevertheless, we obtained the better result than existing method. In future research plan, we have to virtual hole filtering for removal of unnecessary virtual hole.

References:

[1] Garcia, M.; Velazquez, S.; Sappa, A.D.; Basanez, L.: Autonomous sensor planning for 3D reconstruction of complex objects from range images, In Proceedings of the IEEE International Conference on Robotics and Automation, May 1988, 3085-3090.

[2] Kang, J.; Suh, S.: Machinability and set-up orientation for five-axis numerically controlled machining of freeform surfaces, International Journal of Advanced Manufacturing Technology, 13, 1997, 311-25. http://dx.doi.org/10.1007/BF01178251

[3] Kweon, S.; Medeiros, D.J.: Part orientations for CMM inspection using dimensioned visibility maps, Computer-Aided Design, 30(9), 1998, 741-749. http://dx.doi.org/10.1016/S0010-4485(98)00034-7

[4] Lee, K.H.; Park, H.: Automated inspection planning of free-form shape parts by laser scanning, Robotics and Computer Integrated Manufacturing, 16, 2000, 201-10. http://dx.doi.org/10.1016/S0736-5845(99)00060-5

[5] Maver, J.; Bajcsy, R.: Occlusions as a guide for planning the next view, IEEE Transactions on Pattern Analysis and Machine Intelligence, 15(5), 1993, 417-433. http://dx.doi.org/10.1109/34.211463

[6] Mehra, R.; Tripathi, P.; Sheffer, A.; Mitra, N.: Visibility of noisy point cloud data, Computers & Graphics, 34, 2010, 219-230. http://dx.doi.org/10.1016/j.cag.2010.03.002

[7] Park, S.C.: Pencil curve detection from visibility data, Computer-Aided Design, 37(14), 2005, 1492-1498. http://dx.doi.org/10.1016/j.cad.2005.03.004

[8] Scott, W.R.; Roth, G.: View planning for automated three-dimensional object reconstruction and inspection, ACM Computing Surveys, 35(1), 2003, 64-96. http://dx.doi.org/10.1145/641865.641868

[9] Singh, R.; Madan, J.: Systematic approach for automated determination of parting line for die-cast parts, Robotics and Computer Interated Manufacturing, 29, 2013, 346-366. http://dx.doi.org/10.1016/j.rcim.2013.02.002

[10] Spyridi, A.J.; Requicha, A.A.G.: Accessibility analysis for the automatic inspection of mechanical parts by coordinate measuring machines, Proceedings of the IEEE International Conference on Robotics and Automation, 1990, 1284-1289. http://dx.doi.org/10.1109/ROBOT.1990.126176

[11] Wang, R.; Pan, M.; Han, X.; Chen, W.; Bao, H.: Parallel and adaptive visibility sampling for rendering dynamic scenes with spatially varying reflectance, Computer & Graphics, 38, 2014, 374-381. http://dx.doi.org/10.1016/j.cag.2013.10.036