Accurate surface extraction from X-ray CT volumes of ellipsoidal mirrors based on occupancy ratios

Keita Matsunaga[1], Yukie Nagai[1], Junta Kono[2], Yutaka Ohtake[3], Hidekazu Mimura[4]

[1]Graduate School of Systems Design, Tokyo Metropolitan University, Japan, [1]Faculty of of Systems Design, Tokyo Metropolitan University, Japan, [1]Research into Artifacts Center for Engineering, The University of Tokyo, Japan, [1]Graduate School of Engineering, The University of Tokyo, Japan

X-ray technologies enable the analysis and observation of objects and have contributed to various fields, including medical science, material science, and physical chemistry. For better observational resolution, X-ray is highly focused with X-ray reflective focusing devices. Ellipsoidal mirrors have been developed as efficient focusing devices. Each mirror has the form of a cylinder coincident with part of a thin ellipsoid. The inner surface of the cylinder serves as a mirror and requires a high manufacturing accuracy in order to have level of less than ±1 μm deviation from its intended diameter, which is usually 5–10 mm. X-ray computed tomography (CT) scanning is the only technology capable of inspecting the inner surface of manufactured mirrors, and is able to obtain the inner structure of these objects in a non-destructive manner. However, computational errors in CT volumes and discretization errors may cause difficulty in determining the surface position of the mirror. To extract the inner surface of an ellipsoidal mirror from its CT volume with high accuracy, we propose a new surface determination algorithm. Our idea is based on the fact that ellipsoidal mirrors have a very high circularity on the order of nanometers with an unknown radius. Due to their circularity, each surface point should have a certain distance from the center of the cross sectional circle of the mirror. For the relocation of surface points, we define and use a geometric value named the "occupancy ratio," which represents the amount of the mirror contained in the vicinity of a point at the surface. The proposed algorithm iteratively updates the surface points until it reaches a convergence at which the occupancy ratio becomes 50%. We provide experimental results demonstrating that our proposed method can yield better variance of deviation from the radii than existing surface extraction algorithms.