Acquiring axially-symmetric transparent objects using single-view transmission imaging

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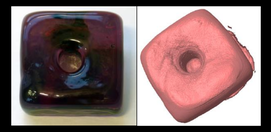
1. Results

A very simple "environment matting" like acquisition setup (a) which consists of the target object placed between a camera and an LCD panel for the efficient acquisition of axially-symmetric transparent objects. (b) A wide range of axially symmetric transparent objects were reconstructed efficiently and accurately by our method. (c) The faithful rendering results show our method can be widely applied for ubiquitous transparent objects in the real world.

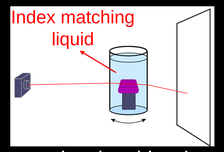
(a) Acquisition setup (b) Comparison between photographs and reconstructed objects (c) Rendering with frontal area light

2. Previous Work

- Tomographic Reconstruction of Transparent Objects, Trifonov et al. [1]



Glass object 3D reconst.



immersing the object into index matching liquid

- Fluorescent Immersion Range Scanning, Hullin et al. [2]

Glass object | Fluorescent Imaging | Reconst. Fluorescent dye + index matching material

❖ Pros
- Applicable to general object shapes

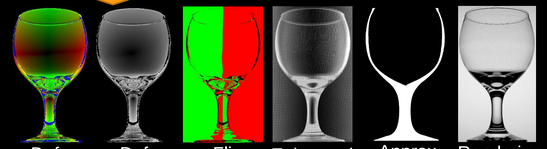
❖ Cons
- Complicated optical setups with liquid, container, special solution, and immersed object
- Cumbersome imaging steps to match the refractive index of liquid to the target object

3. Acquisition and Processing

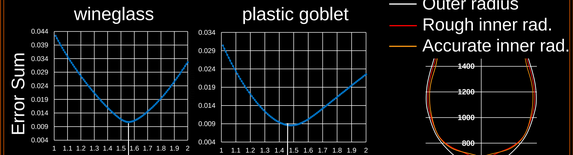
photographs taken with grad. and gray code patterns

Our capture sequence obtains 13 photographs from a single viewpoint:
- 1 constant white screen illumination
- 4 patterns consisting of X and Y linear gradients and their inverses
- 4 patterns each of the X and Y high frequency gray codes

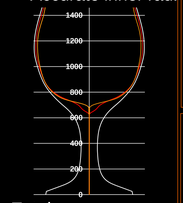
Image Processing



Def. vector | Def. amp | Flip image | Enhanced boundary | Approx. geometry | Rendering



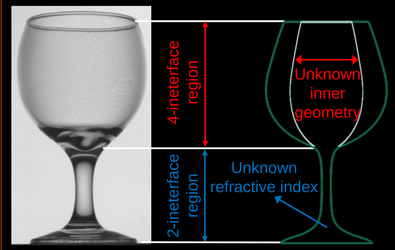
The refractive index is estimated by searching for a value that minimizes the error between ray traced and measured ray deflections.



Est. inner geometry

4. Proposed Method

High quality reconstruction for axially-symmetric transparent objects based on a simple acquisition setup and inverse ray tracing

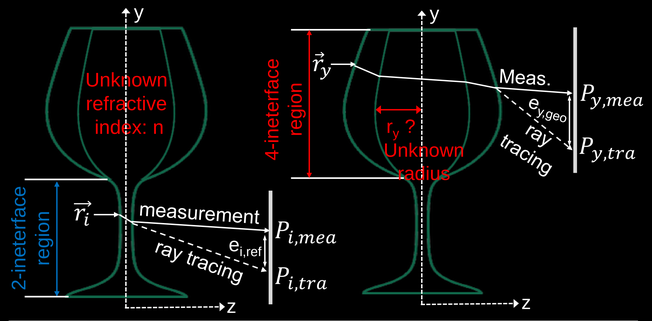


Axially-symmetric transparent object | Modelling of a transparent object

- Identification of 2- & 4-interface regions
- Initial estimation of inner & outer geometry
- Estimation of refractive index in 2-interface region
- Accurate estimation of inner geometry for 4-interface regions
- Rendering of reconstructed 3D Geometry

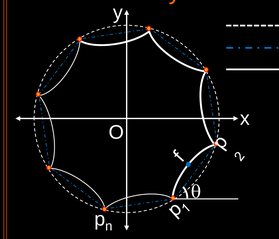
< Algorithm Pipeline >

❖ Step1. Refractive Index Estimation ❖ Step2. Inner Geometry Estimation



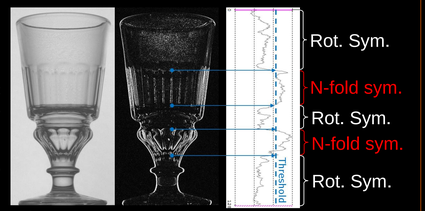
	Refractive Index Estimation	Inner Geometry Estimation
Assum.	Uniform refractive index for the whole volume	Rotational symmetry
Known	Outer geometry and deflection measurement	Refractive Index and deflection measurement
Solution	$\arg\min_{n} \sum_{i \in [x,y]} \lvert P_{i,mea} - P_{i,tra} \rvert$	$\arg\min_{r_y} \sum_{y} \lvert P_{y,mea} - P_{y,tra} \rvert$

5. N-fold Symmetric Objects

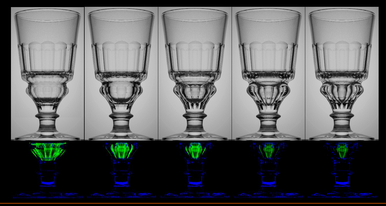


- Given p_1 and p_2, curvature of n-polygonal shape is modeled as rotated quadratic equation by θ
- Outer cross-section in n-fold symmetry is geometrically modeled by only a single input parameter, the number of polygon.

Rotational and n-fold symmetric regions are separated by intensity difference in horizontal projection of vertical edges



Photograph | Vert. edge | Hor. projection



Rendering results (top row) and corresponding residual errors (bottom row) with iterative estimation of inner geometry and curvature of n-fold faces.

6. Conclusion

- Practical approach for high quality reconstruction of axially symmetric transparent objects. Such objects are quite common in the real world and can have very unique, aesthetic and complex shape and appearance.
- Our approach employs a simple environment matting style setup for efficient single view acquisition and robust reconstruction of such transparent objects including estimation of shape and refractive index.
- We demonstrate high quality reconstruction results for a wide range of rotationally symmetric and n-fold symmetric everyday objects.

7. References

[1] B. Trifonov, D. Bradley, and W. Heidrich. Tomographic Reconstruction of Transparent Objects. In Proc. *Eurographics Symposium on Rendering, pages 51–60, 2006*
[2] M. B. Hullin, M. Fuchs, I. Ihrke, H.-P. Seidel, and H. P. A. Lensch. Fluorescent Immersion Range Scanning. *ACM Trans. on Graphics (SIGGRAPH'08), 27(3):87:1 – 87:10, 2008*
[3] C. Ma, X. Lin, J. Suo, Q. Dai, and G. Wetzstein. Transparent Object Reconstruction via Coded Transport of Intensity. *In IEEE Conference on Computer Vision and Pattern Recognition, 2014.*