Volumetric Reconstruction Applied to Perceptual Studies of Size and Weight

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Poster Session 1

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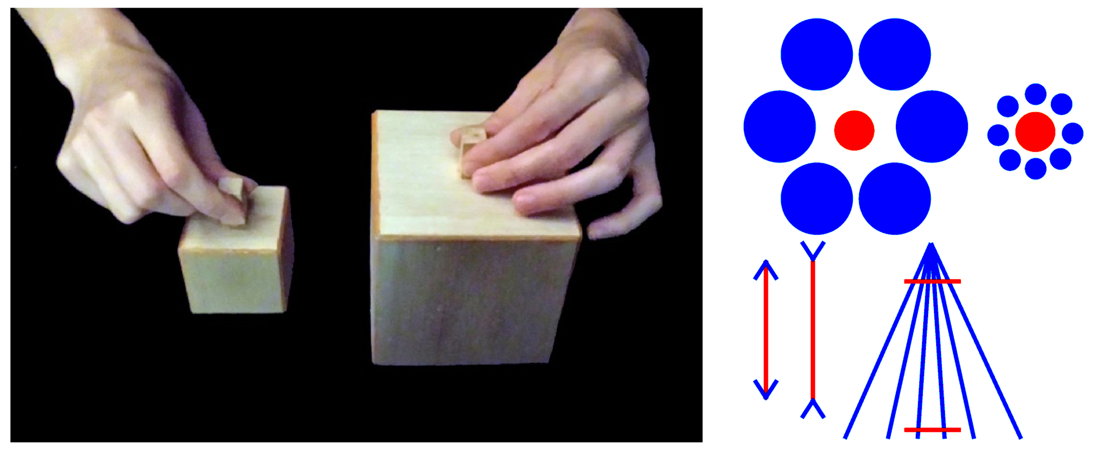
Objective

RGBD scanning system for volume estimation:

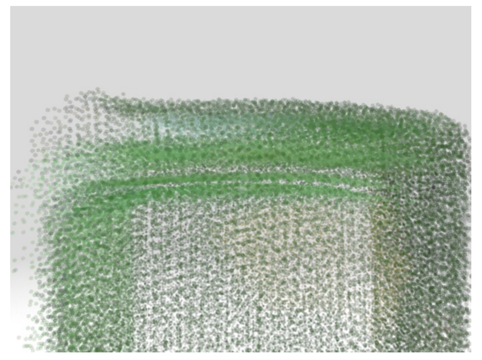
- easy to use for non-experts
- inexpensive
- non-destructive
- recovery of topological structure
- applicable to wide range of shapes and appearances
- more precise than back-of-the-envelope estimates



Size-weight and other illusions

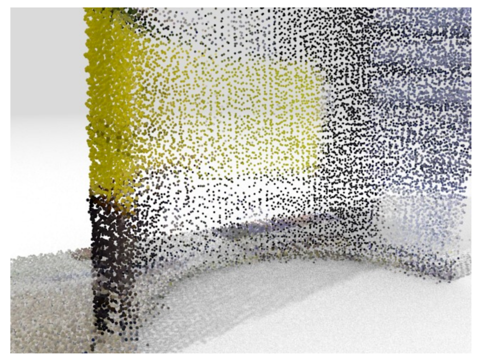
Method

1. View alignment
   - others: tracking
     - no texture required (similarity by closeness)
     - redundancy in depth image stream
       - noise removal by averaging
       - possibly oversmoothing ($\hookrightarrow$ drift)
     - steady motion and static scene required
   - here: RANSAC-type wide-baseline matching
     - hypotheses based on photometric correspondence
     - geometric validation
     - noise removal by Hodge projection

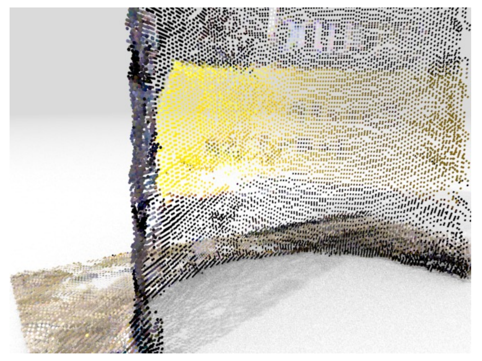


Stratification artefacts

Tracker drift



Scenect



Our method

2. Surface reconstruction
   - topology best recovered by implicit function φ
   - direct estimation (cf. [3] etc.)
   - indirect estimation:

$$\varphi = \arg\min_{\phi} \int_{\mathbb{R}^3} \frac{1}{2}\|\nabla\phi - \boldsymbol{n}\|^2 \,\mathrm{d}\boldsymbol{x}$$

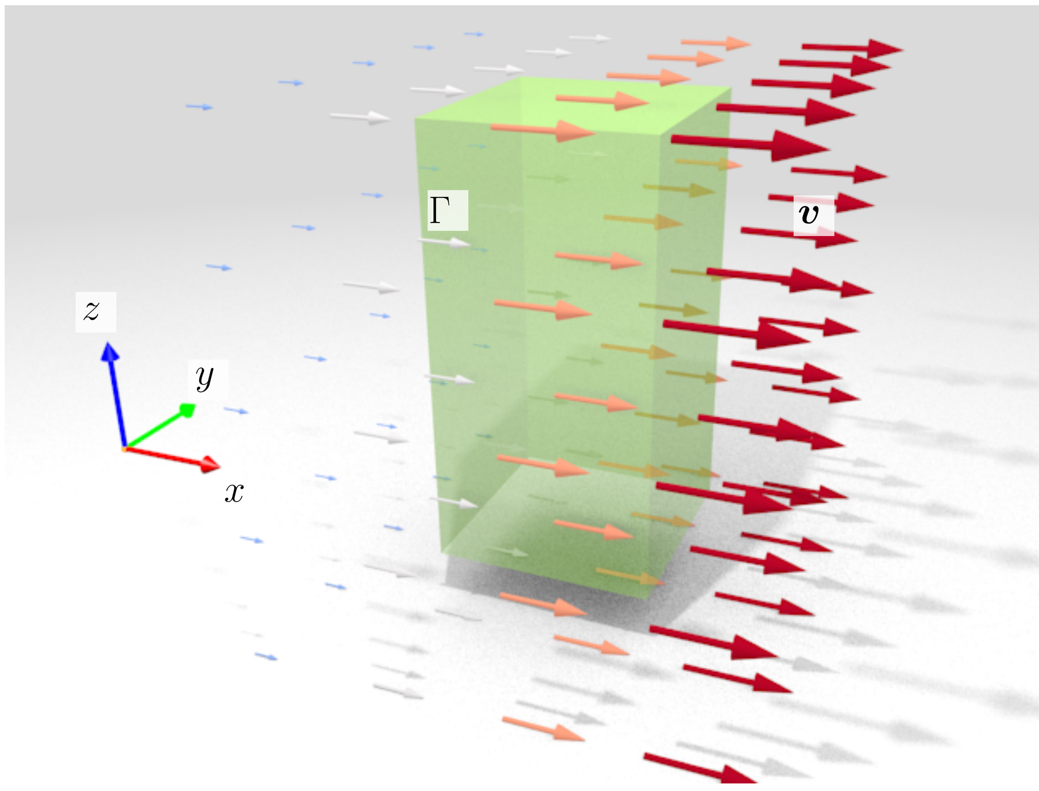
   (*Poisson reconstruction* [2])
   - normals $\boldsymbol{n}$ by finite-differencing on depth channel
   - noise/curl suppressed in $\boldsymbol{n}$ not φ

3. Volume estimation
   - Gauss theorem:

$$\int_{\Omega} \operatorname{div} \boldsymbol{v} \mathrm{d}\Omega = \int_{\Gamma} \langle \boldsymbol{v}, \boldsymbol{n} \rangle \mathrm{d}\Gamma$$

   - choice of $\boldsymbol{v} := (x, 0, 0)^\top$ yields

$$V = \int_{\Gamma} \langle \boldsymbol{v}, \boldsymbol{n} \rangle \mathrm{d}\Gamma$$



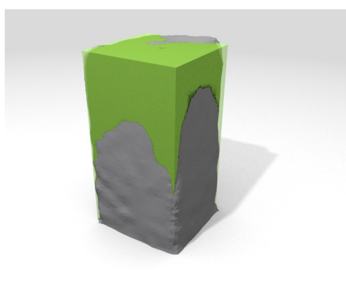
   - hole-filling
     - alignment with robust estimate of ground plane
     - vanishing of flow $\boldsymbol{v}$ through contact surface

Yet Another Scanner (YAS)

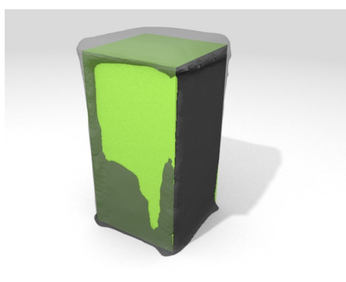
- open-source C++ implementation of complete processing pipeline
- implements sensor model according to [1]
- supports all Primesense/ONI devices
- QT frontend
  - file I/O in various formats
  - maintenance of (calibration) parameters
  - 3d viewer
- dependencies
  - OpenCV
  - QT
  - OpenEXR
  - OpenNI
  - Boost
  - libann
- growing documentation

Download: *http://bitbucket.org/jbalzer/yas*

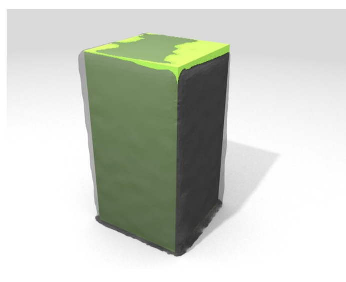
Results



Scenect

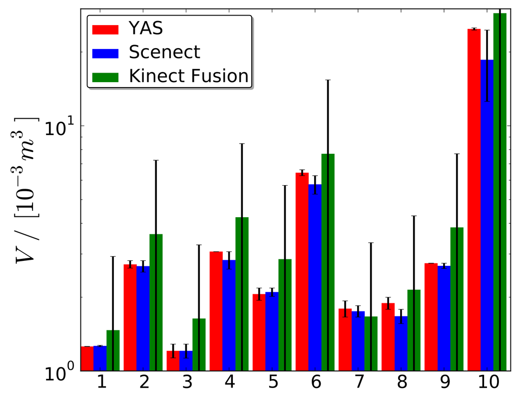


Kinect Fusion [3]

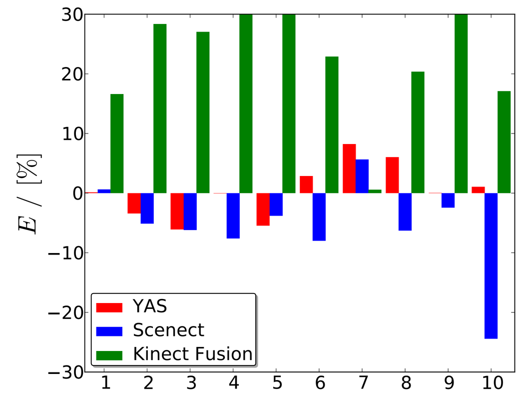


YAS

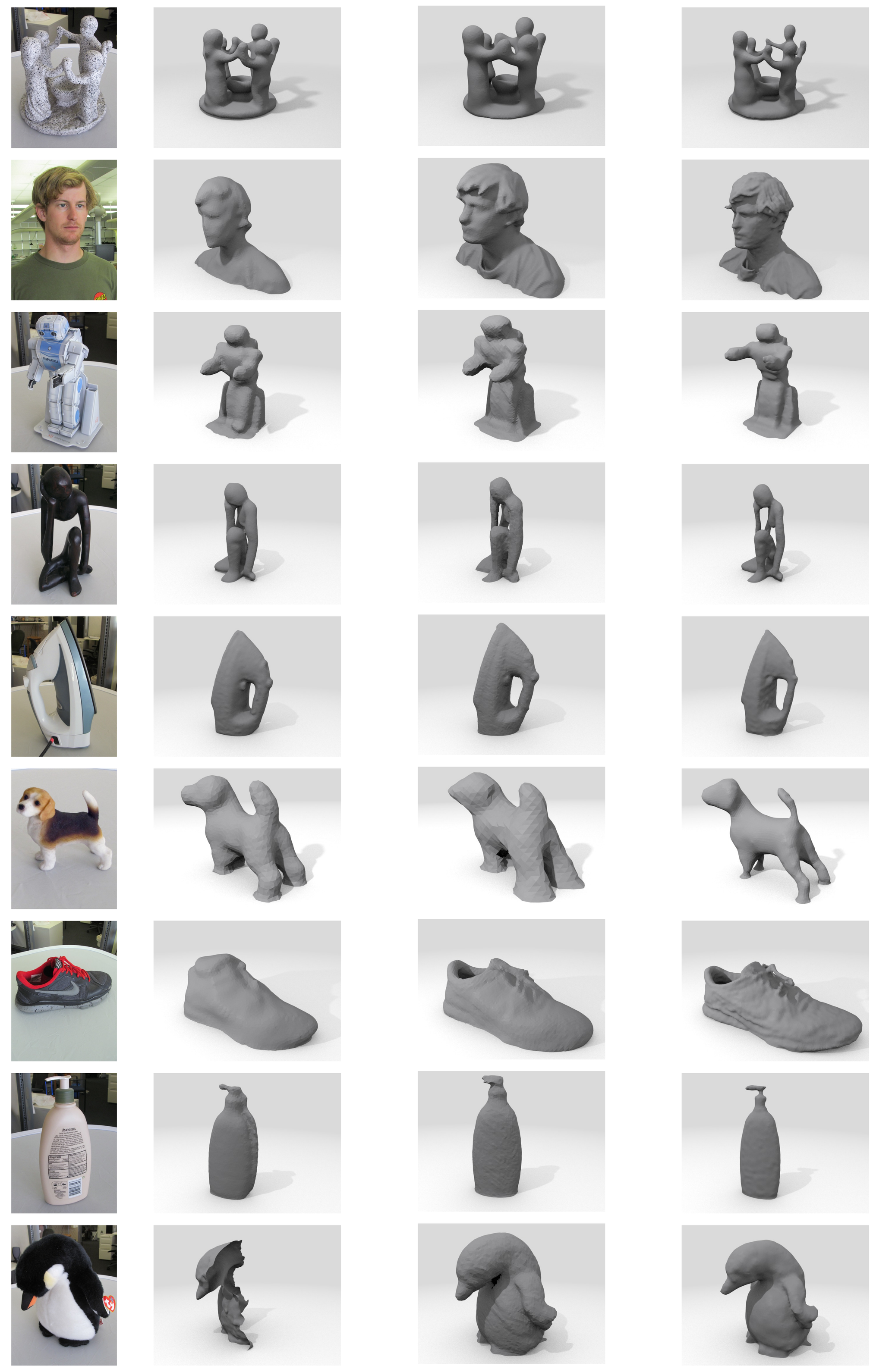
No.	V_{manual} $[10^{-3}m^3]$	V_{YAS} $[10^{-3}m^3]$	E_{YAS} [%]	V_{Scenect} $[10^{-3}m^3]$	E_{Scenect} [%]	V_{KinFu} $[10^{-3}m^3]$	E_{KinFu} [%]
1	1.26	1.26	0.11	1.26	0.6	1.47	16.6
2	2.82	2.72	−3.38	2.68	−5.1	3.61	28.4
3	1.29	1.21	−6.07	1.21	−6.17	1.63	27.0
4	3.07	3.07	−0.02	2.83	−7.57	4.23	38.0
5	2.18	2.06	−5.44	2.1	−3.79	2.85	31.1
6	6.26	6.44	2.86	5.76	−7.07	7.69	22.9
7	1.66	1.79	8.22	1.75	5.65	1.67	0.55
8	1.78	1.89	6.0	1.67	−6.28	2.15	20.3
9	2.75	2.75	0.05	2.68	2.41	3.84	39.8
10	24.6	24.8	1.05	18.6	−24.4	28.8	17.1
μ			−0.34		−5.74		24.2
σ			4.59		7.76		11.5



Volumes



Errors



Object Scenect Kinect Fusion [3] YAS

References

[1] D. Herrera, J. Kannala, and J. Heikkilä. Joint depth and color camera calibration with distortion correction. *IEEE T. Pattern Anal.*, 34(10):2058–64, 2012.

[2] M. Kazhdan and H. Hoppe. Screened poisson surface reconstruction. *ACM Trans. Graph*, 32(1):1–13, 2013.

[3] R.A. Newcombe, D. Molyneaux, D. Kim, P. Koli, A.J. Davison, J. Shotton, S. Hodges, and A. Fitzgibbon. KinectFusion: Real-Time Dense Surface Mapping and Tracking. *IEEE Proc. ISMAR*, 1:127–136, 2011.