Freehand Laser Scanning Using Mobile Phone

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3D scanners are growing in their popularity as many new applications and products are becoming a commodity. These applications are often tethered to a computer and/or require expensive and specialized hardware. In this note we demonstrate that it is possible to achieve good 3D reconstruction on a mobile device. We describe a novel approach for mobile phone scanning which utilizes a smart-phone and a cheap laser pointer with a cylindrical lens which produces a line pattern attached to the phone using a 3D printed adapter as demonstrated in Figure 1. Our 3D reconstruction method is built upon six steps that are preformed online on the mobile device.

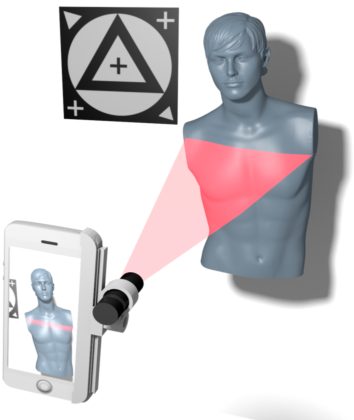

Figure 1: Illustration of the scanning process with a mobile device.

- Calibration
  As a precursor for reconstruction the system must be calibrated. We use openCV [3] for camera intrinsic calibration, and a simple user friendly method for laser plane calibration. This procedure provides all the knowledge about the system configuration that is necessary for 3D reconstruction.

- Pose estimation
  We estimate the camera pose for each captured frame. We use [1] which is able to track a physical marker combined with sparse points in the scene combined with cues from onboard inertial sensors. This library provides an estimated camera position in real time. Another example for camera pose estimation that we tried is the OpenCV checkerboard calibration tool.

- Laser line extraction
  The laser line position is extracted from each frame using an non-linear filteration scheme described by Koller *et al*. [5] and applied by Matiukas and Miniotas [6]. This non-linear combination of filter kernels produces a strong response in the region of the laser line. We estimate the maxima of the response with sub-pixel accuracy using polynomial fitting.

- 3D point reconstruction
  For each image point where the laser line is detected we reconstruct a point in the point cloud. Initially the point is reconstructed relative to the camera using the camera intrinsic calibration and the laser plane calibration. We are then able to reconstruct translate the points into world coordinates using per-frame camera position estimation obtained by the tracking system, by a simple matrix multiplication. Each reconstructed point is added to the final point cloud.

- Per point color recovery
  Due to the fact that each reconstructed point is taken from an area of the image which is colored by the laser, the color cannot be directly inferred. To resolve this issue, we reproject our reconstructed 3D points into an image of the scene captured after a small time interval. This interval allows the laser to pass the reconstructed point and for it's true color to be recovered.

- Surface reconstruction
  Once a dense point cloud is reconstructed, we are able to estimate the surface of the scanned object. This can be done by various reconstruction methods such as Poisson surface reconstruction as demonstrated in Figure 2.

We validate the proposed method by comparing the reconstruction error to the ground truth obtained from an industrial laser scanner. This validation is carried out by scanning the same objects with our scanner and with a highly accurate commercial scanner. We then use the Iterative Closest Point (ICP) [2, 4] to align the scans, allowing a precise measurement of the distortion between the point clouds

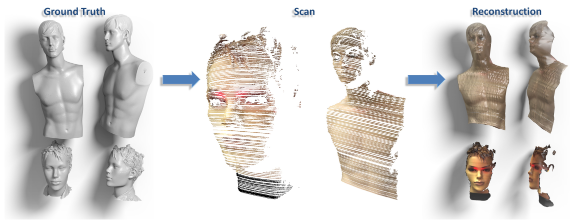

Figure 2: Left: Ground truth models obtained by a professional Artec scanner. Center: Point clouds obtained by our scanning process. Right: Triangle mesh reconstructed from point cloud.

Acknowledgment

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