1. Introduction

Reconstruction of nearly flat 3D objects can be used in many applications, e.g. getting a 3D surface for games, reconstruction of historical fragments etc. The presented approach uses a flatbed scanner to reconstruct a surface of nearly flat objects without calibration and produce a 3D copy of the scanned object using a 3D printer.

Position of the light source and CCD sensor in 2D flatbed scanners is not the same, i.e. light is coming under some angle \( \alpha \), which causes small “shadowed” contours in scanned images. The given object is scanned in four orthogonal positions ideally and if not images have to be transformed appropriately.

![Figure 1: Two of four fundamental orientations in scanning](image)

2. Normal Vector Reconstruction

The CCD sensor of the flatbed scanner is linear and the light source is fixed under angle. Therefore it is possible to reconstruct normal vector \( \mathbf{n} \) for each scanned pixel as the scanned pixel’s intensity \( I_0 \) is given as:

\[
I_0 = \rho \int_{-1}^{1} (n_x a + n_y b) \sqrt{x^2 + a^2 + b^2} \, dx = \rho s (n_x a + n_y b)
\]

where \( s = \int_{-1}^{1} \frac{1}{\sqrt{x^2 + a^2 + b^2}} \, dx = 2\ln \frac{l + \sqrt{l^2 + a^2 + b^2}}{\sqrt{a^2 + b^2}} \)

Similarly it can be computed for other positions. This leads to equations

\[
\begin{bmatrix}
0 & \tan \alpha & 1 \\
-\tan \alpha & 0 & 1 \\
\tan \alpha & 0 & 1
\end{bmatrix}
\begin{bmatrix}
\rho s b n_x \\
\rho s b n_y \\
\rho s b n_z
\end{bmatrix} =
\begin{bmatrix}
l_0 \\
l_{180} \\
l_0
\end{bmatrix}
\]

where:

\[
\rho s b n_x = \frac{l_{270} - l_0}{2 \tan \alpha} \\
\rho s b n_y = \frac{l_0 - l_{180}}{2 \tan \alpha} \\
\rho s b n_z = \frac{l_0 + l_{180} + l_{360} + l_{270}}{4 \tan \alpha}
\]

Also a curvature optimization can be made to obtain better results. However the crucial step is the surface reconstruction from the obtained map of normal’s and boundary conditions, actually height on the object boundary.

![Figure 2: Original object and reconstructed surface](image)

3. Conclusion and Acknowledgment

The presented concept was experimentally verified and 3D reconstructed object was printed on a 3D printer. It should be noted that some 2D scanners produce images with small non-linearity which should be corrected to get better results.

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References


