Directionality-Aware Rectilinear Texture Warped Shadow Maps

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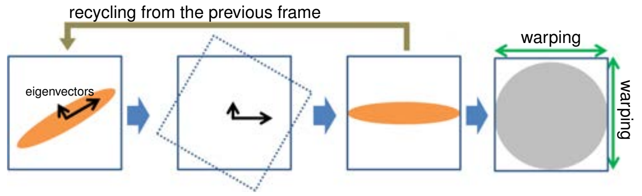
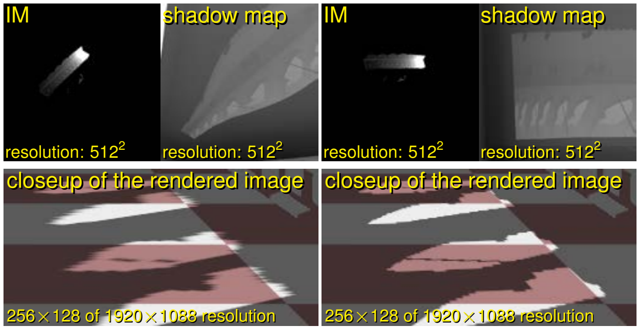
Introduction. Rectilinear texture warped shadow mapping (RTWSM) [Rosen 2012] is a fast and adaptive technique. This technique controls the scene sampling rate via image warping according to a view-dependent importance map (IM). For RTWSMs, one issue is the impact of rotating the light's image plane. Since this plane is only warped with respect to its vertical and horizontal axes, the sampling rate depends on the angle of these axes. This poster proposes a fast technique to estimate an appropriate rotation matrix for RTWSMs by using principal component analysis (PCA) of the IM. Using this rotation, RTWSMs are able to perform more adaptively with small overhead.

Method. Fig. 1 shows our directionality-aware RTWSM pipeline for a frame. First, the rotation matrix is estimated by analyzing the IM of the previous frame (a). Next, the light view frustum is rotated (b). After that, the IM is generated (c), and then the RTWSM is created (d) using the rotated light view frustum. Rosen [2012] proposed forward, backward, and hybrid analyses for the IM generation pass (c). This poster employs backward analysis, since forward and hybrid analyses can increase the importance of surfaces invisible to the camera, and often produce inappropriate importance distribution. The 4×4 rotation matrix of the current frame k is represented by: $\mathbf{R}_k = \mathbf{R}'\mathbf{R}_{k-1}$, where $\mathbf{R}_{k-1}$ is the rotation matrix of the previous frame $k-1$, $\mathbf{R}'$ is the relative rotation matrix between the two frames, and the initial rotation $\mathbf{R}_0$ is the identity matrix. In the estimation pass (a), the relative rotation $\mathbf{R}'$ is obtained via PCA of the IM, since the IM is still rotated by $\mathbf{R}_{k-1}$. PCA is done with mipmap based covariance matrix calculation [Olano and Baker 2010]. The covariance matrix is given as: $\boldsymbol{\Sigma} = \begin{bmatrix}\alpha-\bar{x}^2 & \gamma-\bar{x}\bar{y}\\ \gamma-\bar{x}\bar{y} & \beta-\bar{y}^2\end{bmatrix}$, where $\bar{x} = \frac{\sum_{x,y} xI(x,y)}{\sum_{x,y} I(x,y)}$, $\bar{y} = \frac{\sum_{x,y} yI(x,y)}{\sum_{x,y} I(x,y)}$, $\alpha = \frac{\sum_{x,y} x^2I(x,y)}{\sum_{x,y} I(x,y)}$, $\beta = \frac{\sum_{x,y} y^2I(x,y)}{\sum_{x,y} I(x,y)}$, $\gamma = \frac{\sum_{x,y} xyI(x,y)}{\sum_{x,y} I(x,y)}$, and $I(x,y)$ is the value of the IM at image space position (x,y). To compute $\bar{x}$, $\bar{y}$, α, β and γ, 2D textures of $xI(x,y)$, $yI(x,y)$, $x^2I(x,y)$, $y^2I(x,y)$ and $xyI(x,y)$ are generated, and then those textures and the IM are mipmapped. The weighted averages are then obtained from at the top mip level of these textures. The relative rotation matrix $\mathbf{R}'$ is represented using the unit eigenvector (e_x, e_y) with the largest eigenvalue of $\boldsymbol{\Sigma}$ as: $\mathbf{R}' = \begin{bmatrix} e_x & -e_y & 0 & 0\\ e_y & e_x & 0 & 0\\ 0 & 0 & 1 & 0\\ 0 & 0 & 0 & 1\end{bmatrix}$, where $e_x > 0$. Using this $\mathbf{R}'$, $\mathbf{R}_k$ is computed, and then the light view frustum is rotated in pass (b). When the imaged scene is not changed between consecutive frames, $(e_x, e_y) = (1, 0)$ in theory. However, this eigenvector can have precision error, and the rotated view frustum can vibrate slightly. To avoid this vibration, $\mathbf{R}_k = \mathbf{R}_{k-1}$ is used if $e_x > 0.9999$.



(a) rotation matrix estimation (b) light view frustum rotation (c) IM generation (d) RTWSM creation

Figure 1: *Our directionality-aware RTWSM pipeline. Our contributions are (a) and (b). The passes (c) and (d) are the same as the original RTWSM.*



w/o rotation with rotation

Figure 2: *Quality comparison of RTWSMs with and without rotation of light view frustum for Crytek® Sponza (262 k triangles).*

Table 1: *Computation times for Fig. 2 (ms).*

Rotation matrix estimation & light view frustum rotation	0.12
IM generation	0.70
RTWSM creation	1.24

Results. Fig. 2 and Table 1 show experimental results performed on an NVIDIA® GeForce® GTX™780. Non-linear rasterization for warping is done by using GPU tessellation. Our technique warps the shadow map more appropriately especially for regions distant to the camera. Thus, sharper shadows are rendered with 0.12 ms overhead, and the total shadow mapping time is 2.06 ms. RTWSMs without rotation produce moderate importance distribution for both vertical and horizontal axes when importance is obliquely distributed. By using our rotation, sharper importance distribution is produced for the vertical axis. Although our method uses the IM of the previous frame for PCA, any error due to delay is unnoticeable, because the rotation matrix is temporally coherent for most scenes.

References

OLANO, M., AND BAKER, D. 2010. LEAN mapping. In *Proc. I3D'10*, 181–188.

ROSEN, P. 2012. Rectilinear texture warping for fast adaptive shadow mapping. In *Proc. I3D'12*, 151–158.

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SIGGRAPH 2014, August 10 – 14, 2014, Vancouver, British Columbia, Canada.

ACM 978-1-4503-2958-3/14/08