Non-rigid Photometric Stereo with Colored Lights

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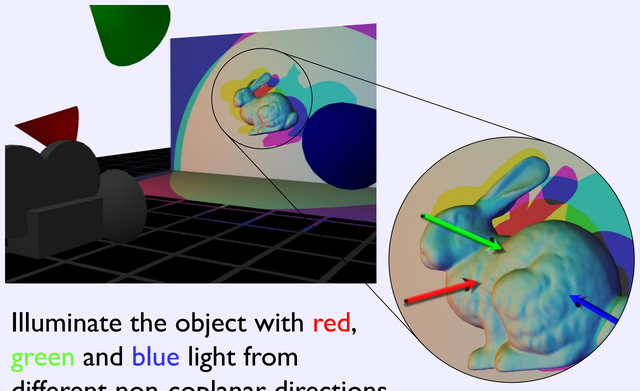
Key Idea

If a white object is illuminated by a red, a green and a blue light source, the color reflected by a point on the surface is in 1-1 correspondence with local orientation.



Illuminate the object with red, green and blue light from different non-coplanar directions.

One color image simultaneously captures **three** images under different illumination.

Background

Un-textured deforming 3D objects are difficult to capture using surface features, structured light, or silhouettes.

Novelty

• Multi-spectral photometric stereo is an attractive alternative because it can recover a dense normal field from an un-textured surface.

• We show how to capture such video data and register it over time to generate a single deforming 3D surface.

Why this is important

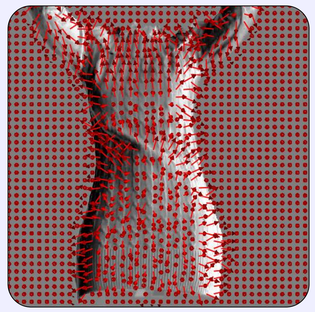
• It is a simple and practical acquisition setup for acquiring high-detail, per-frame 3D reconstructions.

• Simple technique for capturing real moving cloth and 'dressing' a virtual character.

Algorithm

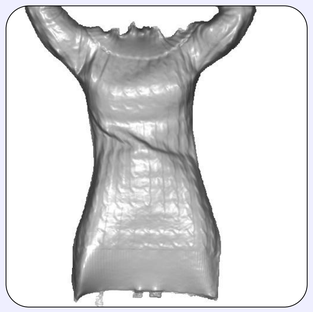
Single frame from video

$$[i_R \quad i_G \quad i_B]^T = \mathbf{I} = \mathbf{L}_{3\times3} \cdot \mathbf{n}$$



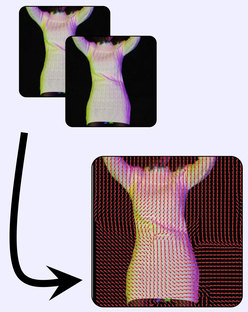
Color is converted to a normal at each pixel

$$\mathbf{n} = \mathbf{L}_{3\times3}{}^{-1} \cdot \mathbf{I}$$

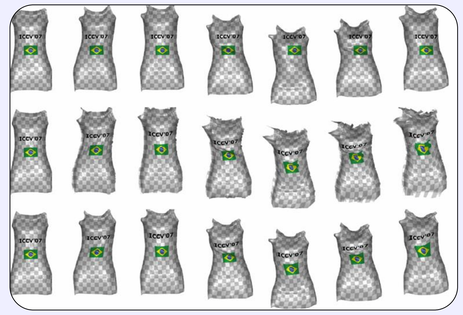


Normals integrated using SOR Poisson solver

$$\Delta z = \nabla \cdot \mathbf{n}$$



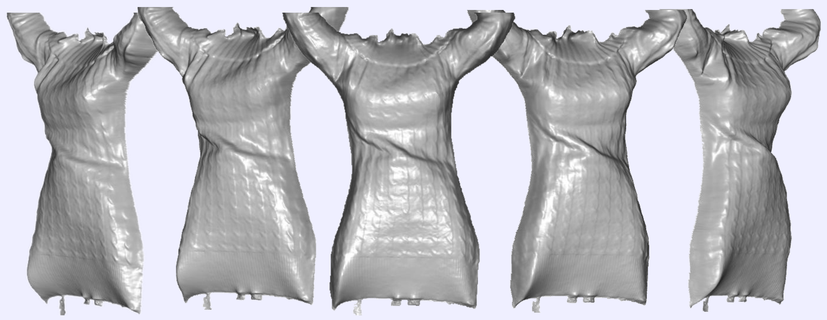
Optical flow



Adding a rigidity constraint improves registration over time

$$E_R(\mathbf{T}_1^t, \ldots, \mathbf{T}_N^t) = \sum_{i,j \in \varepsilon} \| \mathbf{T}_i^t - \mathbf{T}_j^t \|$$

Applications

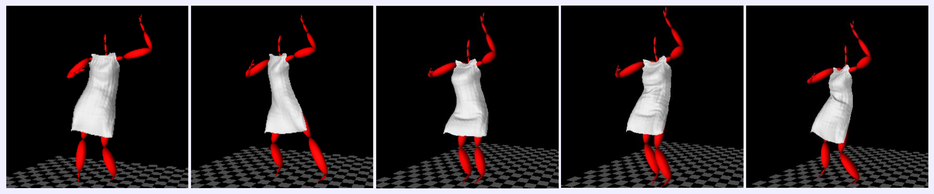


Views of a single reconstructed frame at several angles (frontal, ±25°, ±50°)

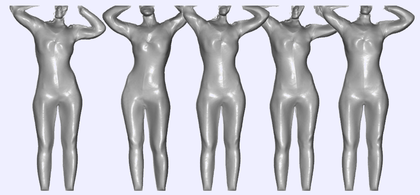
Classic photometric stereo

Our method

Classic photometric stereo shot with a 4MPixel camera vs. our reconstruction of one frame of video. Average mesh distance is only 1.4% of the bounding box diagonal

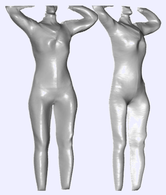


Moving reconstructed cloth is soft-bound to an animated skeleton, "dressing" our avatar

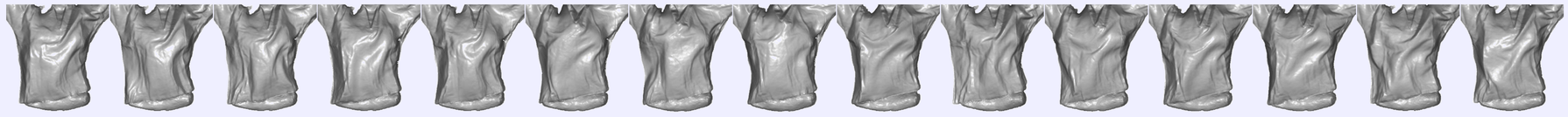


Spandex reconstruction

Self shadow failure and recovery



Lambertian limitation



Reconstructed meshes of a shirt flapping in the wind