Projection of Images Onto Non-Flat Surface Using Depth Camera Technology

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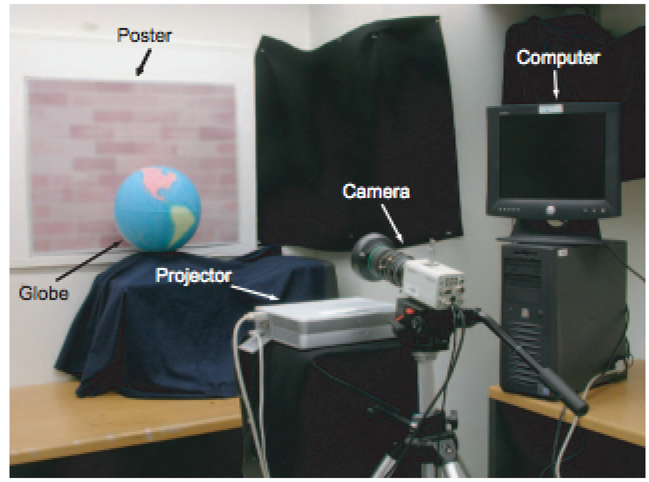
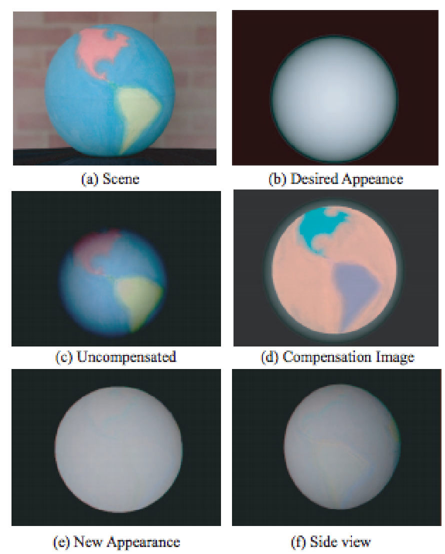
Introduction: In the past, "smart projector" systems were made which allowed for projection of images onto non-flat surfaces [1, 2, 3]. These systems relied on prior construction of a pixel displacement map by projecting a calibration image into the scene, and using an RGB image of the scene in order to understand the scene's structure [1, 2]. Furthermore, local color correction of the projected image can be applied to reduce artifacts caused by the spectral reflectance of the surfaces in the scene [1, 4].



More recently, the emergence of RGB-D camera technology has allowed for the capture of 3D reconstructions of scenes. I want to explore the integration of such technology into the aforementioned "smart projector" systems in order to eliminate this calibration step and allow for proper projection into dynamic (moving) scenes. The process for radiometric compensation should be similar to existing systems given that RGB data is still available along with depth cameras.



Timeline (estimations include time not spent on the project):

1) Achieve proper off-line pixel-mapping using input from RGB-D camera on simple non-flat scenes. 3 weeks total.

   Day 1-5:

   a) Fix a transform between the camera and the projector.
   b) Attain a depth image of the surface to be projected on.

   Day 5-17:

   c) From the depth image, calculate the 3D world-space areas (these will be squares projected onto 3D surfaces) of each 2D pixel projected from the projector. (This can be done using raycasting techniques given the FOV of the projector and its position and orientation in space).
   d) Now, reproject all of these "squares" on a single axis back onto a virtual "viewing plane." The viewing plane should be oriented with its normal close to the direction of the audience, and additionally, close to the direction of the projector.

   Day 17-21:

   e) Subdivide the "viewing plane" into axis-aligned pixels matching the dimensions of the projector. For each pixel in the viewing plane *p*, map it to the projector pixel which, when transformed onto the viewing plane using the process described above, occupies the most area in *p*.

f) Now, any image can be displayed with spatial compensation in the scene by applying the mapping attained in part e).

2) Using radiometric theory, calibrate camera-projector system to allow for color compensation of projected image. 2 weeks total..
   Day 21-35
   a) implement approach modeled after [1] replacing traditional camera input with RGB input from depth camera.

Stretch Goals:

3) Achieve on-line pixel-mapping using input from RGB-D camera on moving scene.
4) Support the use of multiple camera-projector systems in order to eliminate shadows in projection. Van Baar et. al write about seamless multi-projector displays, which could be applicable here.

Logistics:
I have an XBox Kinect, and would have to acquire a projector…. Any leads on a projector would be much appreciated!

References:

[1] Grossberg, Michael D., Harish Peri, Shree K. Nayar, and Peter N. Belhumeur. "Making one object look like another: Controlling appearance using a projector-camera system." In *Computer Vision and Pattern Recognition, 2004. CVPR 2004. Proceedings of the 2004 IEEE Computer Society Conference on*, vol. 1, pp. I-452. IEEE, 2004.

[2] Bimber, Oliver, Andreas Emmerling, and Thomas Klemmer. "Embedded entertainment with smart projectors." *Computer* 38, no. 1 (2005): 48-55.

[3] Van Baar, Jeroen, Thomas Willwacher, Srinivas Rao, and Ramesh Raskar. "Seamless multi-projector display on curved screens." In *Proceedings of the workshop on Virtual environments 2003*, pp. 281-286. ACM, 2003.

[4] Fujii, Kensaku, Michael D. Grossberg, and Shree K. Nayar. "A projector-camera system with real-time photometric adaptation for dynamic environments." In *2005 IEEE Computer Society Conference on Computer Vision and Pattern Recognition (CVPR'05)*, vol. 1, pp. 814-821. IEEE, 2005.